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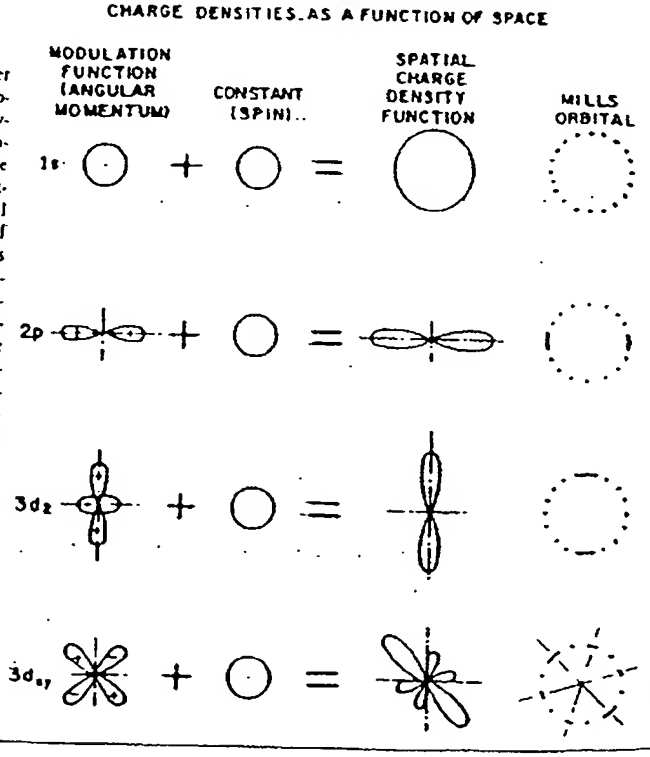
(57) Abstract

Methods and structures of energy/matter conversion according to the present invention provides applications including the generation of power according to controlled relatively low temperature nuclear fusion by selective annihilation of the coulombic forces present in the fusion material atoms. The selective annihilation of electron orbital energies is provided according to a novel model of the atom described herein, which further provides the composition of superconductor materials by selective combination of matter to provide the conditions necessary to provide superconductivity. Furthermore, the present invention provides selective energy absorption, as illustrated by photon absorption and the creation of additional material according to the novel model of the atom described herein, which overcomes limitations of prior models and is consistent with basic principles, such as Maxwell's equations.



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ENERGY/MATTER CONVERSION METHODS AND STRUCTURES

Field of the Invention

This invention relates to methods and apparatus for energy/matter conversion according to a novel atomic model and the applications derived therefrom including controlled nuclear fusion and the formation of materials such as superconductors.

BACKGROUND

Toward the end of the 19th century, many physicists believed that all of the principles of physics had been discovered. The laws then discussed and accepted, now called "classical physics," included laws relating to Newton's mechanics, Gibb's thermodynamics, LaGrange and Hamilton's elasticity and hydrodynamics, Maxwell-Boltzmann molecular statistics, and Maxwell's equations. However, a discrepancy between nature and the understanding provided by prevailing laws was discovered in the case of black body radiation, wherein classical physics predicted the intensity to go to infinity as a function of temperature while experimentally it goes to zero. In 1900, Planck made the revolutionary assumption that energy levels were quantized which resulted in a model which was consistent with experimentation. Models of the atom were developed by Bohr based on the concept of quantized energy levels. Bohr's model was in agreement with the observed hydrogen spectrum; however, it failed with the helium spectrum and could not account for chemical bonds in molecules. It was reasoned that Bohr's model failed because it was based on the application of Newtonian mechanics to a discrete particle, and its limited applicability was due to the unwarranted condition that the energy levels be quantized. Quantization occurs in wave motion; hence, in 1923 de Broglie suggested that electrons have a wave aspect analogous to light with $\lambda = h/p$, where λ is the wavelength, h is Planck's constant, and p is the momentum.

In 1927, Davisson and Germer experimentally confirmed de Broglie's hypothesis by observing diffraction effects by reflecting electrons from metals. Schrodinger reasoned further that if electrons have wave properties, then there must be a wave equation that governs their motion. In 1926, Schrodinger proposed that the Schrodinger equation, $H\Psi = E\Psi$,

was the law which governs the motion of electrons (where Ψ is a wave function, H is a wave operator and E is the energy of the wave). This equation and its associated postulates provides the basis for the field of quantum mechanics. Quantum mechanics requires that physics on an atomic scale are quite different from that on a macroscopic scale. However, it entails postulates which are not proven, but are assumed to be absolute laws of nature. Central to quantum mechanics is that it is statistical in nature. Knowing the state, a position measurement cannot be predicted with certainty, and only the probabilities of various possible results can be predicted as reflected in the Heisenberg Uncertainty Principle: $\sigma p\, \sigma x \geq \hbar$ which is fundamental to the prevailing view of quantum mechanics and establishes the lower bound for the uncertainty of two observables. The Heinsberg Uncertainty Principle states that the product of the uncertainty in position and the uncertainty in momentum of an electron must be greater than $\hbar$ where $\hbar$ is Planck's constant divided by 2π. Prevailing understanding of quantum mechanics does not provide that an electron is distributed over a larger region of space as a wave is distributed. Rather, it is believed that the probability patterns (wave functions) used to describe the electron's motion behave like waves and satisfy a wave equation $\psi(x)$.

Max Born interpreted $\psi^*(x)\psi(x)dx$ to be the probability that the electron is located between x and x + dx, where ψ^* is the complex conjugate of $\psi(x)$, and this interpretation is generally accepted. However, Born's view results in intangible concepts which conflict with known physical laws. For example, it results in overlap of negative probability density in molecules, the possibility of an electron instantaneously traveling from the nucleus to infinity and back which violates conservation of energy; radial kinetic energy which violates conservation of energy and angular momentum, and acceleration of a charged particle without radiation which violates Maxwell's equations. Schrodinger had a different interpretation of $\psi(x)$ as a charge density function, but his interpretation also produces radiation which is contrary to experimentation as described in Appendix III.

With respect to the interpretations of Born and Schrodinger, problems have arisen concerning the realization of kinetic energy, spin, and angular

momentum of the electron. For instance, there is no time dependence of the stationary state wave equation; furthermore, the hypothesized electron-electron repulsions in multiple electron atoms violates the law of conservation of energy. Moreover, the Schrodinger equation provides no rational basis for the phenomenon of spin, the Paul Exclusion Principle, or Hund's Rule. Also, bonding requires exchange of electrons between atoms which would result in violation of conservation of energy and angular momentum.

As a result of the forgoing assumptions and incomplete or erroneous models and theories, the numerous resulting conflicting models prevent the development of useful or functional systems and structures requiring an accurate understanding of atomic structure and energy transfer. The Schrodinger equation, for example, does not explain the high transition-temperature superconductors or "cold" nuclear fusion which comprise the present invention. Thus, advances in materials and energy/matter conversion is largely limited to laboratory discoveries having limited or sub-optimal commercial application.

SUMMARY OF THE INVENTION

The methods and structures according to the present invention provide unique applications of energy/matter conversion according to a novel mathematical model of the atom consistent with Maxwell's equations and principles of conservation of energy and angular momentum. According to the present invention, methods and apparatus for the useful generation of energy are provided wherein fusionable material is selected from a wide range of possible elements wherein the orbital energies of the fusionable material are determined. The energy of the electrons is selectively depleted by an energy hole provided by one or more selective materials placed in close proximity to the fusionable material. Fusion is permitted to occur at a rate determined by the relative equality of the orbital energies and the energy hole. According to one embodiment, the rate of fusion is adjusted by the external control of energies transferred into or out of the vicinity of the fusionable material and the energy hole to selectively adjust the equivalence of the energies. The energy produced by the resulting fusion of the nuclei of the fusionable material is received in a surrounding material which serves to energize or propel apparatus for the generation of power, such as electric power or steam.

A further product according to the present invention is the selective production of matter, including byproducts of the above described fusion, and matter having special characteristics, such as superconductor material. Furthermore, the atomic structure and energy of existing matter is selectively adjustable according to the present invention, such as by selectively reducing or increasing the electron orbitals by depletion of energy as described above or selection absorption, such as resonant photon absorption described according to the present invention. Time and spherical harmonic angular charge density functions and their energies and angular momenta which describe the electron before and after a transition are consistent with the laws of conservation of energy and angular momentum. The radial component of the charge density waves of the novel atomic model provides that the entire charge density function of three dimensional space and time does not radiate. The condition for zero radiation is the absence of Fourier components of the space-time transform that are synchronous with waves traveling at the speed of light as described in Appendix I and Appendix II.

The boundary condition of the radial function which forces the charge density function to be nonradiative and the result that the moment of inertia of each said function is a function of quantum numbers naturally give rise to the wavelike nature of the electron. The wavelength is identical to the de Broglie wavelength, $\lambda = h/p$, for all these functions that describe the electron and its energy in space-time and are hereafter referred to as Mills orbitals possessing energy, hereafter referred to as the Mills energy. To distinguish the basis of the present invention from the prior art, the mechanics of the present novel atomic model is hereinafter referred to as Mills mechanics.

The electron orbitals according to the novel atomic model, referred to as Mills orbitals, are spherically symmetric charge density functions which are the product of a radial delta function, two angular spherical harmonic functions, and a time harmonic function. Each orbital is the sum of a constant Mills orbital which rotates with a quantized angular velocity and a Mills orbital charge density modulation function which also rotates with a quantized angular velocity to result in a traveling wave of charge density on the surface of the sphere. The time harmonic motion of the former gives rise to the phenomenon of magnetic spin of one Bohr

magneton for the electron. The latter time harmonic traveling naturally gives rise to orbital angular momentum. The interaction of the independent time harmonic motions gives rise to spin-orbital coupling, and the predicted spin, orbital angular momentum, and the associated energies are in exact agreement with experimentation.

The energy of an electron is stored in its electric and magnetic fields. Orbital energies are approximately equal to ionization energies. The orbital energies of several one- and two-electron atoms juxtaposed with their experimentally determined ionization energies appear in Table I and Table II.

Photon absorption by an electron with a transition to a higher energy Mills orbital arises naturally where a standing traveling wave of the photon is formed inside of the Mills orbital. This photon wave is a solution of Laplace's equation in spherical coordinates; thus, it is a spherical harmonic. The photon wave rotates in both directions simultaneously, or it rotates in the opposite direction of the spin or angular momentum of the Mills orbital to change the spin or angular momentum by one quantum which is carried by the photon, thus, the selection rules ΔM; $\Delta S = 0, \pm 1$ for transitions arise naturally from conservation of angular momentum.

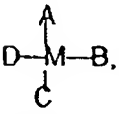
The electric field of an electron of a Mills orbital in the ground state is zero inside the orbital and is the field of a point charge at the origin outside of the orbital; thus, electron-electron repulsions are naturally eliminated in multi-electron atoms.

The radii of orbitals in atoms are calculated in turn by setting the centripetal force equal to the sum of the coulombic and magnetic forces. Thus, the result that isolated Mills orbitals are stable where the coulombic attractive force does not cause the electron to collapse into the nucleus arises naturally. For all atoms and ions, there exists a central coulombic force acting on each orbital that is proportional to the net charge (that is the charge not cancelled by other electrons). A positive central magnetic spin pairing force exists between two unpaired electrons which results in pairing in the same shell with spins opposed. Thus, the Pauli Exclusion Principle arises naturally. A diamagnetic repulsive central force exists between paired electrons of an inner shell and an unpaired electron of an outer shell. A four body problem does not arise because the change in the centripetal force of the inner shell electrons affected by the

outer electron is exactly balanced by the Lorentzian force provided by the magnetic field of the outer shell electron; thus, it is possible to calculate the exact radius and exact energy of the Mills orbital of any electron of any atom. Illustrative examples appear in Table 1 and Table 2.

The electric field of a Mills orbital is zero inside the shell, and this feature naturally gives rise to the chemical bond. Bonding between atoms occurs because the overlap of Mills orbitals of two atoms reduces the total energy stored in the electric fields of the participating atoms. The bond distance of the H_2 molecule is determined in accordance with the present invention and shown Appendix V to be the experimentally confirmed value of .748Å.

Mills orbitals are spherical, and the radius increases with the absorption of electromagnetic energy. When the electron is ionized the radius of the Mills orbital goes to infinity, and the electron is a plane wave with the de Broglie wavelength. The plane wave nature of an electron is consistent with the results of prior double slit experiments. Furthermore, coupling of two such plane waves which are 180° out of phase as a zero phonon event provides Cooper pair formation and provides the basis of a model which provides for superconductors of high transition temperature which is the present invention. These materials comprise one or two dimensional lattices that contain atoms whose electrons can be ionized by an applied electric or magnetic field. Moreover, the lattice is of low symmetry so that the existence of symmetric phonons is improbable. Interactions of said phonons and Cooper's pairs causes the pairs to break. A representative two-dimensional unit cell is



, where M is a metal and A, B, C, and D are different atoms or different oxidation states of the same atom or atoms.

Mills orbitals can resonantly absorb an energy hole, and, as a consequence, the radius decreases. With sufficient decrease in radius the electron can annihilate a proton to form a neutron. Thus, K capture arises naturally from this phenomenon.

Furthermore, outside of the outermost Mills orbital of a neutral atom, the electric field of the nucleus is zero; thus, as the radii of atoms resonantly decrease, atoms can approach more closely before nuclear

coulombic repulsive forces occur. And, with sufficient decrease, the nuclei of atoms, such as deuterium atoms in deuterium molecules, can approach sufficiently for fusion to occur at relatively low temperature. This process of providing low temperature fusion according to the present invention is hereafter referred to as Coulombic Annihilation Fusion (CAF). For deuterium, CAF requires a source of energy holes of slightly greater energy than 27 eV ($n/2$ 27.21 eV; $n = 2,3,4,...$) to cause a resonant radius reduction of a Mills orbital of the deuterium atom. An illustration of such an energy hole system is Pd^{2+} and Li^{+} which catalytically removes a quantum of energy during each cycle of a reaction where the oxidation states increase and decrease by one, respectively, and are regenerated by the reverse redox reaction. Also, the present invention provides for many more such energy hole systems.

BRIEF DESCRIPTION OF THE DRAWINGS

The present invention is further described with respect to the drawings having the following solely exemplary figures, wherein:

Figure 1 is a pictorial illustration of Mills orbitals of the novel atomic model;

Figure 2 is a pictorial illustration of the magnetic field lines of an electron in a Mills orbital in an un-ionized state;

Figure 3 is a pictorial illustration of two approaching hydrogen atoms;

Figure 4 is a pictorial illustration of the two hydrogen molecules as their Mills orbitals spatially overlap;

Figure 5 is a pictorial illustration of the electric field vectors when the Mills orbitals of two hydrogen atoms penetrate; and

Figure 6 is a block diagram of a fusion reactor according to one embodiment of the present invention.

DETAILED DESCRIPTION OF THE INVENTION

Principles

Conservation of mass-energy, conservation of linear and angular momentum, Maxwell's equations, and Newtonian mechanics for sublight speeds are absolute laws of nature. Thus, a body in equilibrium which is not acting on or being acted on by another body possesses constant mass-energy, constant angular momentum, force balance, and is not radiating. And, a body not at equilibrium exchanges mass-energy and angular momentum in a conservative manner until the body is again at equilibrium.

An isolated atom or molecule qualifies as such a body, and a novel model of the atom and molecules hereafter referred to as Mills mechanics is derived based solely on these principles, and the charge/mass density functions which describe the electron are Mills orbitals.

Mills Orbitals

Consider the body of an isolated hydrogen atom at rest in three-dimensional space. All forces are central and the coordinate system is spherical. The mass-energy and angular momentum are constant which necessitates that the equation of motion of the electron of the atom be a time harmonic. Conservation of angular momentum further necessitates that the electron space-time angular mass density function must be a solution of a wave equation given in general form as follows:

$$\left(\nabla^2 + \frac{1}{v^2}\frac{\delta}{\delta + 2}\right) A(\sigma, \phi, t) = 0$$

Spherical harmonics are general solutions of this equation. Conservation of momentum and energy in the absence of external forces or energy exchange determine that the angular functions must be separable.

The electron has a charge of 1.6×10^{-19}C and possesses an angular space-time mass density function which is a spherical and time harmonic. Charge is conserved and obeys superposition; thus, the mass density function of an electron is equivalent to its charge density function which depending on the form of its separable radial function will radiate due to the time harmonic angular acceleration of charge. The condition for radiation by moving charge is derived from Maxwell's equations in Appendix I. To radiate, the space-time Fourier transform of the charge density function must possess components synchronous with waves traveling at the speed of light. Thus, the product of two spherical harmonic functions, a time harmonic function, and a radial function must not possess space-time Fourier components that are synchronous with waves traveling at the speed of light. The solution of this boundary value problem is the radial function given as follows:

$$f(r) = \delta(r - r_0)$$

The boundary condition for the product of the said four functions which results in the absence of radiation is given in Appendix II. For an angular frequency of $\omega = \omega_0$, the space-time Fourier transform is zero when $2\pi r = n\lambda$. This function, with the boundary condition $2\pi r = n\lambda$ is a Mills orbital.

The boundary condition requires that the electron possess a wavelength λ. The wavelength of an electron is the de Broglie wavelength,

$$\lambda = \frac{h}{\rho}.$$

The exact forms of the angular and time harmonic functions can now be solved from the wave equation in spherical coordinates. The form of the wave equation for the angular and time harmonic functions is as follows:

$$\left(\nabla^2 + \frac{1}{v^2}\frac{\delta^2}{\delta t^2}\right) A(\theta, \phi, t) = 0$$

$$\left(\frac{1}{r^2 \sin\theta}\frac{\delta}{\delta\theta}\left(\sin\theta\left(\frac{\delta}{\delta\theta}\right) r,\phi + \frac{1}{r^2 \sin^2\theta}\left(\frac{\delta^2}{\delta\phi^2}\right) r,\theta + \frac{1}{v^2}\frac{\delta^2}{\delta t^2}\right) A(\theta, \phi, t) = 0\right.$$

The energy, E, of a rotating body is given as follows: $E = 1/2\ I\omega^2$, where I is the body's moment of inertia and ω is its angular velocity. The angular velocity ω is related to the frequency υ as follows:

$$\omega = 2\pi\upsilon$$

And, the wavelength, λ, can be expressed in terms of the frequency υ and velocity v as follows:

$$\upsilon\lambda = v$$

Substitution of these relationships into the wave equation gives the result,

$$\frac{-\hbar^2}{2I}\left[\frac{1}{\sin\theta}\frac{\delta}{\delta\theta}\left(\sin\theta\left(\frac{\delta}{\delta\theta}\right) + \frac{1}{\sin^2\theta}\left(\frac{\delta^2}{\delta\phi^2}\right)\right] A(\theta, \phi, t) = E\ A(\theta, \phi, t)\right.$$

The time harmonic function $K(t) = e^{i\omega_0}$ is separable and is cancelled yielding the following equation:

$$\frac{-\hbar^2}{2I}\left[\frac{1}{\sin\theta}\frac{\delta}{\delta\theta}\left(\sin\theta\left(\frac{\delta}{\delta\theta}\right) + \frac{1}{\sin^2\theta}\frac{\delta^2}{\delta\phi^2}\right]\right. Y(\theta, \phi) = E\ Y(\theta, \phi) \qquad (6\text{-}46)$$

If we multiply Eq. 6-46 by $\sin^2\theta$ and let

$$\beta = \frac{2IE}{\hbar^2}$$

we find the partial differential equation

$$\sin\theta\frac{\delta}{\delta\theta}\left(\sin\theta\frac{\delta Y}{\delta\theta}\right) + \frac{\delta^2 Y}{\delta\phi^2} + \beta\sin^2\theta\, Y = 0 \qquad (6\text{-}48)$$

To solve this partial differential equation, we use the method of separation of variables and let

$$Y(\theta, \phi) = g(\theta)\, h(\phi) \qquad (6\text{-}49)$$

If we substitute Eq. 6-49 into Eq. 6-48 and then divide by $\Theta(\theta)\Phi(\phi)$, we

find

$$\frac{\sin\theta}{g(\theta)}\frac{d}{d\theta}\left(\sin\theta\frac{dg}{d\theta}\right)+\beta\sin^2\theta+\frac{1}{h(\phi)}\frac{d^2h}{d\phi^2}=0 \qquad (6\text{-}50)$$

Because θ and ϕ are independent variables, we must have that

$$\frac{\sin\theta}{g(\theta)}\frac{d}{d\theta}\left(\sin\theta\frac{dg}{d\theta}\right)+\beta\sin^2\theta=m^2 \qquad (6\text{-}51)$$

and

$$\frac{1}{h(\phi)}\frac{d^2h}{d\phi^2}=-m^2 \qquad (6\text{-}52)$$

where m^2 is a constant. Note that Eqs. 6-51 and 6-52 add up to Eq. 6-50.

Equation 6-52 is relatively easy to solve, and its solutions are

$$h(\phi)=A_m e^{im\phi} \text{ and } h(\phi)=A_{-m}e^{-im\phi} \qquad (6\text{-}53)$$

The requirement that $h(\phi)$ be continuous is that

$$h(\phi+2\pi)=h(\phi) \qquad (6\text{-}54)$$

By substituting Eq. 6-53 into Eq. 6-54, we see that

$$A_m e^{im(\phi+2\pi)}=A_m e^{im\phi} \qquad (6\text{-}55)$$

and that

$$A_{-m}e^{-im(\phi+2\pi)}=A_{-m}e^{-im\phi} \qquad (6\text{-}56)$$

Equations 6-55 and 6-56 together imply that

$$e^{\pm i2\pi m}=1 \qquad (6\text{-}57)$$

In terms of sines and cosines, Eq. 6-57 is

$$\cos(2\pi m)\pm i\sin(2\pi m)=1$$

which implies that $m = 0, \pm1, \pm2,\ldots$, because $\cos 2\pi m = 1$ and $\sin 2\pi m = 0$ for $m = 0, \pm1, \pm2,\ldots$ Thus Eq. 6-53 can be written as one equation

$$h_m(\phi)=A_m e^{im\phi} \quad m=0,\pm1,\pm2,\ldots \qquad (6\text{-}58)$$

We can find A_m by requiring that the $h_m(\phi)$ be normalized. The normalization condition is that

$$\int_0^{2\pi} d\phi\; h_m^*(\phi)h_m(\phi)=1$$

Using Eq. 6-58 for the $h_m(\phi)$, we have

$$|A_m|^2\int_0^{2\pi}d\phi=1$$

or

$$|A_m|^2 2\pi = 1$$

or

$$A_m = (2\pi)^{-1/2}$$

Thus, the normalized version of Eq . 6-58 is

$$h_m(\phi) = \frac{1}{(2\pi)^{1/2}} e^{im\phi} \quad m = 0, \pm 1, \pm 2,... \qquad (6\text{-}59)$$

The solution to Eq. 6-51 is obtained by the power series method. We shall not present all the details for the solution to Eq. 6-51, but when one does solve Eq. 6-51, it turns out naturally that ß in Eq. 6-47 must obey the condition

$$ß = l(l+1) \qquad l = 0, 1, 2,... \qquad (6\text{-}60)$$

Using the definition of ß, Eq. 6-60 is equivalent to

$$E_l = \frac{\hbar^2}{2I} l(l+1) \qquad l = 0,1,2,... \qquad (6\text{-}61)$$

A set of discrete energy levels are obtained.

The charge density functions of Mills orbitals are given by the solutions to Eq. 6-46. To solve Eq. 6-46, we assumed separation of variables and wrote $Y(\theta,\phi) = g(\theta)\, h(\phi)$ (Eq. 6-49) . The resulting differential equation for $h(\phi)$ (Eq. 6-52) is relatively easy to solve, and we showed that its solutions are (Eq. 6-59). The differential equation for $g(\theta)$, (Eq. 6-51), is not easy to solve. It is convenient to let $x = \cos\theta$ and $g(\theta) = P(x)$ in Eq. 6-51. Because $0 \le \theta \le \pi$, the range of x is $-1 \le x \le +1$. Under the change of variable, $x = \cos\theta$, Eq. 6-51 becomes

$$(1 - x^2)\frac{d^2P}{dx^2} - 2x\frac{dP}{dx} + \left[l(l+1) - \frac{m^2}{1-x^2}\right]P(x) = 0 \qquad (6\text{-}69)$$

In Eq. 6-69 we have used the fact that $ß = l(l + 1)$(Cf. Eq. 6-60). Equation 6-69 for $P(x)$ is called Legendre's equation and is a well-known equation in classical physics. It occurs in a variety of problems that are formulated in spherical coordinates. When the power series method of solution is applied to Eq. 6-69, the series must be truncated in order that the solutions be finite at $x = \pm 1$. It is this truncation that yields Eq. 6-60. The solutions to Eq. 6-69 when $m = 0$ are called Legendre polynomials and are denoted by $P_l(x)$. Legendre polynomials arise in a number of physical problems. The first few Legendre polynomials are given in Table 6-1.

Table 6-1

The First Few Legendre Polynomials, Which Are the Solutions to Eq. 6-69

with m = 0. The Subscript Indexing the Legendre Polynomials Is the Value of l in Eq. 6-69.

$$P_0(x) = 1$$
$$P_1(x) = x$$
$$P_2(x) = 1/2\,(3x^2-1)$$
$$P_3(x) = 1/2\,(5x^3-3x)$$
$$P_4(x) = 1/8\,(35x^4-30x^2+3)$$

Notice from Table 6-1 that $P_l(x)$ is an even function if l is even and an odd function if l is odd. The factors in front of the $P_1(x)$ are chosen such that $P_l(1) = 1$. In addition, although we shall not prove it, it can be shown generally that the $P_1(x)$ in Table 6-1 are orthogonal or that

$$\int_{-1}^{1} dx P_l(x) P_n(x) = 0 \qquad l \neq n \tag{6-70}$$

Keep in mind here that the limits on x correspond to the natural, physical limits on θ(0 to π) in spherical coordinates because $x = \cos\theta$. The Legendre polynomials are normalized by the general relation, which we simply present:

$$\int_{-1}^{1} dx\,[P_l(x)]^2 = \frac{2}{2l+1} \tag{6-71}$$

Equation 6-71 shows that the normalization constant of $P_l(x)$ is $[(2l+1)/2]^{1/2}$.

Although the Legendre polynomials arise only in the case m = 0, they are customarily studied first because the solutions for the m ≠ 0case, called associated Legendre functions, are defined in terms of the ordinary Legendre functions. If we denote the associated Legendre polynomials by $P_l^{|m|}(x)$, then their defining relation is

$$P_l^{|m|}(x) = (1-x^2)^{|m|/2} \frac{d^m}{dx^m} P_l(x) \tag{6-72}$$

Note that only the magnitude of m is relevant here because the defining differential equation, Eq. 6-69, depends on only m^2. The first few associated Legendre functions are given in Table 6-2.

Before we go on to discuss a few of the properties of the associated Legendre polynomials, let us be sure to realize that it is θ and not x that is the variable of physical interest. Table 6-2 also lists the associated Legendre polynomials in terms of cos θ and sin θ. Note that the factors $(1 - x^2)^{l/2}$ in Table 6-2 become sin θ when the associated Legendre functions are expressed in the variable θ. Because $x = \cos\theta$, Eqs. 6-70 and 6-71 are

$$\int_{-1}^{1} P_l(x) P_{n(x)} dx = \int_{0}^{\pi} d\theta \sin\theta \, P_l(\cos\theta) P_n(\cos\theta) = \frac{2\delta_{ln}}{2l+1} \qquad (6\text{-}73)$$

Because the differential volume element in spherical coordinates is $d\tau = r^2 \sin\theta \, dr \, d\theta \, d\phi$, we see that the factor sin θ $d\theta$, in Eq. 6-73, is the "θ part" of $d\tau$ in spherical coordinates.

Table 6-2

The First Few Associated Legendre Functions $P_l^{|m|}(x)$

$P_0^0(x)$	$=1$
$P_1^0(x)$	$= x = \cos\theta$
$P_1^1(x)$	$= \sqrt{1 - x^2} = \sin\theta$
$P_2^0(x)$	$= 1/2(3x^2 - 1) = 1/2(3\cos^2\theta - 1)$
$P_2^1(x)$	$= 3x\sqrt{1 - x^2} = 3\cos\theta\sin\theta$
$P_2^2(x)$	$= 3(1 - x^2) = 3\sin^2\theta$
$P_3^0(x)$	$= 1/2(5x^3 - 3x) = 1/2(5\cos^3\theta - 3\cos\theta)$
$P_3^1(x)$	$= 3/2(5x^2 - 1)(1 - x^2)^{1/2} = 3/2(5\cos^2\theta - 1)\sin\theta$
$P_3^2(x)$	$= 15x(1 - x^2) = 15\cos\theta\sin^2\theta$
$P_3^3(x)$	$= 15(1 - x^2)^{3/2} = 15\sin^3\theta$

The associated Legendre functions satisfy the relation

$$\int_{-1}^{1} dx\, P_l^{|m|}(x)\, P_n^{|m|}(x) = \int_0^{\pi} d\theta \sin\theta\, P_l^{|m|}(\cos\theta)\, P_n^{|m|}(\cos\theta)$$

$$= \frac{2}{(2l+1)} \frac{(l + |m|)!}{(l - |m|)!} \delta_{ln} \qquad (6\text{-}74)$$

Equation 6-74 can be used to show that the normalization constant of the associated Legendre functions is

$$N_{lm} = \left[\frac{(2l+1)}{2} \frac{(l - |m|)!}{(l + |m|)!}\right]^{1/2} \qquad (6\text{-}75)$$

Returning to the original problem now, Eq. 6-46, the Mills orbitals

functions are $P_l^{|m|}(\cos\theta)h_m(\phi)$. By referring to Eqs. 6-59 and 6-75, we see that the functions

$$Y_l^m(\theta, \phi) = \left[\frac{(2l + 1)}{4\pi} \frac{(l - |m|)!}{(l + |m|)!}\right] P_l^{|m|}(\cos\theta)\, e^{im\phi} \qquad (6\text{-}76)$$

are solutions to Eq. 6-46. The $Y_l^m(\theta, \phi)$ form an orthonormal set

$$\int_0^{2\pi} d\phi \int_0^{\pi} d\theta \sin\theta\, Y_l^m(\theta,\phi)^*\, Y_n^k(\theta,\phi) = \delta_{nl}\delta_{mk} \qquad (6\text{-}77)$$

Note that the $Y_l^m(\theta, \phi)$ are orthonormal with respect to $\sin\theta\, d\theta\, d\phi$ and do not just $d\theta\, d\phi$. The factor $\sin\theta\, d\theta\, d\phi$ has a simple physical interpretation. The differential volume element in spherical coordinates is $r^2 \sin\theta\, dr\, d\theta\, d\phi$ If r is a constant, as it is in the case of a radial delta function, and set equal to unity for convenience, then the spherical coordinate volume element becomes a surface element, $dA = \sin\theta\, d\theta\, d\phi$. If this surface element is integrated over θ and ϕ, we obtain 4π, the surface area of a sphere of unit radius. Thus, $\sin\theta\, d\theta\, d\phi$ is an area element on the surface of a sphere of unit radius. According to Eq. 6-77, the $Y_l^m(\theta, \phi)$ are orthonormal over a spherical surface and so are called spherical harmonics. The first few spherical harmonics are given in Table 6-3.

Table 6-3
The First Few Spherical Harmonics

$$Y_0^0 = \frac{1}{(4\pi)^{1/2}}$$

$$Y_1^0 = \left(\frac{3}{4\pi}\right)^{1/2} \cos\theta$$

$$Y_1^1 = \left(\frac{3}{8\pi}\right)^{1/2} \sin\theta\, e^{i\phi}$$

$$Y_1^{-1} = \left(\frac{3}{8\pi}\right)^{1/2} \cos\theta\, e^{-i\phi}$$

$$Y_2^0 = \left(\frac{5}{16\pi}\right)^{1/2} (3\cos^2\theta - 1)$$

$$Y_2^1 = \left(\frac{15}{8\pi}\right)^{1/2} \sin\theta \cos\theta\, e^{i\phi}$$

$$Y_2^{-1} = \left(\frac{15}{8\pi}\right)^{1/2} \sin\theta \cos\theta\, e^{-i\phi}$$

$$Y_2^2 = \left(\frac{15}{32\pi}\right)^{1/2} \sin^2\theta\, e^{2i\phi}$$

$$Y_2^{-2} = \left(\frac{15}{32\pi}\right)^{1/2} \sin^2\theta\, e^{-2i\phi}$$

The angular functions of Mills orbitals are spherical harmonics, and the angular kinetic energy is given as

$$E_k = \frac{\hbar^2}{2I} l(l+1) \quad l = 0, 1, 2, \ldots$$

The angular kinetic energy E_k is related to the angular momentum, L, by the following relationship:

$$E_k = \frac{L^2}{2I}$$

Thus, $L = \hbar\sqrt{l(l+1)}$ $l = 0, 1, 2, \ldots$

Mills orbitals are the product of the angular, radial, and time functions which are given as follows:

$$M(r, \theta, \phi, t) = Y(\theta, \phi)\, \delta(r - r_o)\, e^{i\omega_o t}$$

$Y(\theta,\phi)$ is a function of $e^{im\phi}$ for $l \neq 0$. The product $e^{im\phi}e^{i\omega_o t} = e^{i(m\phi + \omega_o t)}$ is a traveling wave with angular frequency ω_o.

The angular frequency can be derived from the angular momentum energy as follows:

$$E = \frac{1}{2} I \omega^2 = \frac{\hbar^2}{2I} l(l + 1)$$

$$\omega^2 = \frac{\hbar^2}{I^2} l(l + 1)$$

$$\omega = \frac{\hbar}{I} \sqrt{l(l + 1)}$$

In addition to the spherical harmonics of Table 6-3, $Y_{1/2}^{1/2}$ and $Y_{1/2}^{-1/2}$, with $l = 1/2$

is also a solution to equation 6-46. A Mills orbital of one of these functions is a time harmonic spinning charge density function, and it can be shown that this Mills orbital always possesses a magnetic moment of one Bohr magneton, ß, given as follows:

$$\beta = \frac{e\hbar}{2\mu}$$

where e is the charge and μ is the mass of the electron and $\hbar$ is Planck's constant divided by 2π. The angular momentum of these functions is distinguished from that of the former solutions by assigning it the variable S, the spin angular momentum of the electron which is given as follows:

$$S = \hbar \sqrt{s(s + 1)}$$

$$S = 1/2$$

$$m_S = \pm 1/2$$

And, the angular momentum, L, is defined as orbital angular momentum.

A sum of independent solutions to Eq. 6-46 is a solution, and the same condition applies to the boundary condition for nonradiation. Thus, the Mills orbital of the electron is given as the sum of the following functions:

$$M(r, \theta, \phi, t) = Y_l^{m_l}(\theta, \phi)\, \delta(r - r_o)\, e^{i\omega_1 t} + Y_s^{m_s}(\theta, \phi)\, \delta(r - r_o)\, e^{i\omega_2 t}$$

where

$$\omega_1 = \frac{\hbar}{I}\sqrt{l(l+1)} \qquad l = 0, 1, 2, \ldots$$

$$\omega_2 = \frac{\hbar}{I}\sqrt{s(s+1)} \qquad s = 1/2$$

Thus, it is apparent that a Mills orbital is a spherical shell of charge/mass density of zero width where the charge/mass is a base function defined by $Y_s^{m_s}$ to which is added a component of modulation of mass/charge density given by $Y_l^{m_l}$ where the total charge is e, the charge of an electron, and the total mass is μ, the mass of the electron. (Diagrams of several representative Mills orbitals are given in Figure1.) The two components are independent time harmonics which rotate in the same or opposite directions. The interaction of the two independent components gives rise to spin-orbital coupling.

It can be demonstrated that the moment of inertia of the orbital angular momentum and spin angular momentum are given respectively as follows:

$$I_{spin} = \mu r^2\sqrt{s(s+1)}$$

$$I_{angular} = \mu r^2\sqrt{l(l+1)}$$

where μ is the mass of the electron and r is the radius of the Mills orbital. Substitution of this result into the angular frequency relationships gives:

$$\omega_1 = \frac{\hbar}{I}\sqrt{l(l+1)} = \frac{\hbar\sqrt{l(l+1)}}{\mu r^2\sqrt{l(l+1)}} = \frac{\hbar}{\mu r^2}$$

$$\omega_s = \frac{\hbar}{I}\sqrt{s(s+1)} = \frac{\hbar\sqrt{s(s+1)}}{\mu r^2\sqrt{s(s+1)}} = \frac{\hbar}{\mu r^2}$$

The linear velocity is obtained from the angular velocity by the following equation:

$$v = r\omega$$

Thus, the linear velocity of the spin and orbital Mills orbitals is given as follows:

$$v = \frac{\hbar}{\mu r}$$

To prove this result is consistent with the boundary condition for nonradiation, the wavelength is derived from this result and the boundary condition, $2\pi r = n\lambda$; $n = 1,2,3,...$ as follows:

$$K = \frac{2\pi}{\lambda} = \frac{\omega}{v} = \frac{\hbar}{\mu r^2 v}$$

$$\frac{1}{\lambda} = \frac{h}{2\pi r 2\pi r \mu v}$$

$$\frac{1}{\lambda} = \frac{h}{\lambda \mu v}$$

$$\lambda = \frac{h}{p}$$

Position and Energies of Mills Orbitals

The radius of each Mills orbital can be calculated by equating the centripetal force with the other central forces. The forces are as follows:

1.) coulombic attractive force of the positively charged nucleus for the negatively charged Mills orbital;

2.) an attractive magnetic spin pairing force between two unpaired electrons which causes them to be at the force balance at the same radius with vectorially opposed spins; thus, the magnetic moments cancel;

3.) a repulsive diamagnetic force between two paired electrons and an unpaired electron where the radius of the former is unaffected by this force.

Only the coulombic force is involved in the one electron atom. The coulombic and the spin-pairing forces are involved in two electron atoms, and the coulombic and diamagnetic forces are involved in calculating the radius of the third electron of a three electron atom, where the previously calculated radius of the inner shell comprising two spin-paired electrons is used in the calculation. The orbital energy of any electron can be calculated from the calculated radius as the energy stored in its electric and magnetic fields. (The magnetic field of an electron and the energy

stored in the magnetic field of two electrons is given in Appendix IV. A magnetic field diagram of an electron is given in Figure 2.) Examples of one-, two-, and three-electron atoms are given below which demonstrate the said forces. And, it is further demonstrated, in the case of lithium, that the sum of the orbital energy and the change in orbital energies of the two remaining inner shell electrons following ionization is equal to the experimentally determined first ionization energy of lithium.

The One-Electron Atom

centripetal force $= \frac{\mu v^2}{r}$

centripetal electrostatic force $= \frac{(+Ze)(-e)}{4\pi\varepsilon_o r^2} = \frac{-Ze^2}{4\pi\varepsilon_o r^2}$

(obtained by taking the gradient of the electrostatic potential)

We can solve for the radius of the electron shell by balancing these forces.

$$\frac{\mu v^2}{r} = \frac{Ze^2}{4\pi\varepsilon_o r^2}$$

The boundary condition is $2\pi r = n\lambda$ which gives $\omega = \frac{\hbar}{n\mu r^2}$; $v = r\omega$; thus, $v = \frac{\hbar^2}{n\mu r}$. When an electron in the ground state absorbs a photon of sufficient energy to take it to a new non-radiative state, n = 2, 3, 4, ..., force balance must be maintained. This is possible only if we let $Z_{eff} = \frac{Z}{n}$ and, therefore,

$$\frac{\mu v_n^2}{r_n} = \frac{Z_{eff} e^2}{4\pi\varepsilon_o r_n^2}$$

The reduction of the charge from Ze to Ze/n is caused by trapping a photon in the orbitsphere cavity—a spherical cavity.

Therefore,

$$r = \frac{4\pi\varepsilon_o n\hbar^2}{Ze^2\mu} = \frac{na_o}{Z} \qquad (1)$$

The energy stored in the electric field of the orbitsphere, E_{ele} ,is

$$E_{ele} = (\tfrac{1}{2})\,\varepsilon_o \int_0^{2\pi}\int_0^{\pi}\int_{\infty}^{\frac{na_o}{Z}} E^2 dv = (\tfrac{1}{2})\,\varepsilon_o \int_0^{2\pi}\int_0^{\pi}\int_{\infty}^{\frac{na_o}{Z}} \frac{Ze^2}{16\pi^2\varepsilon_o{}^2 n r^4}\, r^2 \sin\theta\, dr d\theta d\phi$$

where the electric field,E, is

$$E = 0,\ r < a_o;\ E = \frac{e}{4\pi\varepsilon_o r^2},\ r \geq a_o$$

$$E_{ele} = \frac{Ze^2}{8\pi\varepsilon_o n}\int_{\infty}^{\frac{na_o}{Z}} \frac{1}{r^2}\, dr = -\frac{Z^2 e^2}{8\pi\varepsilon_o a_o n^2} = -\frac{Z^2}{n^2}\ (2.17714(10)^{-18})\ J$$

$$E_{ele} = -\frac{Z^2}{n^2}\,(13.589)\ eV \qquad (2)$$

Equations (1) and (2) can be used for any one-electron atom. The energies for several one-electron atoms are shown in Table 1.

Table 1 Calculated energies (non-relativistic) and calculated ionization energies for some one-electron atoms (without realtivistic correction).

Atom	Energy (eV)[a]	Ionization Energy (eV)
H	-13.589	13.595
He^{+}	-54.35	54.587
Li^{2+}	-122.28	122.45
Be^{3+}	-217.40	217.71
B^{4+}	-339.68	340.22
C^{5+}	489.14	489.98
N^{6+}	665.77	667.03
O^{7+}	869.58	871.39

[a]from equation (2)

The Two-Electron Atom

$$\text{centripetal force} = \frac{\mu v^2}{r}$$

$$\text{centripetal electrostatic force} = -\frac{(Z-1)e^2}{4\pi\varepsilon_o r^2}$$

$$\text{centripetal magnetic force} = -\frac{1}{Z}\frac{\hbar^2}{\mu r^3}\sqrt{S(S+1)}$$

(obtained by taking the gradient of the angular momentum energy)

Consider two indistinguishable electrons where each is subject to an effective nuclear charge of Z-1 due to cancellation of one nuclear charge by the other electron. Each electron has a positive spin pairing force for the other. The balance of force equations is as follows:

For $n = 1$, $v^2 = \frac{\hbar^2}{\mu r^2}$

$$\frac{\mu v^2}{r} = \frac{\hbar^2}{\mu r^3} = \frac{(Z-1)e^2}{4\pi\varepsilon_o r^2} + \frac{1}{Z}\frac{\hbar^2}{\mu r^3}\sqrt{S(S+1)}$$

and,

$$r = a_o\left(\frac{1}{Z-1} - \frac{\sqrt{S(S+1)}}{Z(Z-1)}\right) \qquad (3)$$

The electrostatic energy is

$$E_{ele} = \frac{(Z-1)e^2}{8\pi\varepsilon_o r} \qquad (4)$$

The magnetic energy is

$$E(\text{magnetic}) = \frac{2\pi\mu_o e^2\hbar^2}{\mu^2 r^3} \qquad (5)$$

(The energy stored in the magnetic field of an electron is derived in Appendix IV.)

Table II The calculated electrostatic and magnetic energies for some two-electron atoms (without relativistic corrections).

Atom	Atomic Number	$R(a_0)$[a]	Electrostatic Energy[b] (eV)	Magnetic Energy[c] (eV)	Total Energy (eV)	Experimental Ionization Energy (eV)
He	2	0.567	-23.96	-0.63	-24.59	24.587
Li	3	0.356	-76.41	-2.54	-78.95	75.638
Be	4	0.261	-156.08	-6.42	-162.50	153.893
B	5	0.207	-262.94	-12.96	-275.90	259.368
C	6	0.171	-396.98	-22.83	-419.81	392.077
N	7	0.146	-558.20	-36.74	-594.93	552.057
O	8	0.127	-746.59	-55.35	-801.95	739.315
F	9	0.113	-962.17	-79.37	-1,041.54	953.886

[a]from equation (3)
[b]from equation (4)
[c]from equation (5)

Three-Electron Atom
(First Ionization Energy of Lithium)

From the Li^{2+} (see Table 2), it was determined that there are two oppositely spin-paired electrons in a shell with the radius

$$r = a_o\left[\frac{1}{2} - \frac{\sqrt{\frac{3}{4}}}{6}\right]$$

The next electron is added to form a new shell. This is a consequence of a repulsive force that exists between the two spin-paired electrons and the spin unpaired electron. This repulsive magnetic force arises from the phenomenon of diamagnetism involving the magnetic field produced by the outer electron and the two paired electrons of the inner shell.

(The following calculation is given by Edward Purcell in Electricity and Magnetism, p. 370-389. The diamagnetic force of the two paired inner shell electrons acting on the outer shell electrons is given as

$$F = \frac{-mv_o\Delta v}{r} \qquad \frac{\Delta v}{r} = \frac{eB}{2\mu} = \frac{eB}{4\mu} \qquad v_o = \frac{\hbar}{\mu r_o}$$

where r_1 is the radial distance of the first shell from the origin.

$$F = -\frac{\hbar}{4r_1}\frac{eB}{\mu}$$

The magnetic flux is that supplied by the constant field inside the shell of the outer electron and is given by:

$$B = \frac{\mu_o e\hbar}{\mu r^3} \text{ ; therefore,}$$

$$F = -\frac{\hbar^2}{4\mu r^2}\frac{1}{r_1}\frac{e^2\mu_o}{\mu r}$$

$$\frac{e^2\mu_o}{\mu r} = \sqrt{s(s+1)}$$

$$F = -\frac{\hbar^2}{4\mu r^2 r_1}\sqrt{s(s+1)}$$

The radius of the orbital for the outer electron of lithium is calculated by equating the centripetal force to the sum of the coulombic and diamagnetic forces as follows:

$$\frac{\mu v^2}{r} = \frac{e^2}{4\pi\varepsilon_o r^2} \cdot \frac{\hbar^2}{4\mu r^2 r_1}\sqrt{s(s+1)}$$

$$v = \frac{\hbar}{\mu r} \quad \text{and} \quad r_1 = a_o\left[\frac{1}{2} - \sqrt{\frac{\frac{3}{4}}{6}}\right]; \text{ thus,}$$

$$\frac{\hbar^2}{\mu r^3} = \frac{e^2}{4\pi\varepsilon_o r^2} - \frac{\hbar^2}{4\mu r^2 a_o\left[\frac{1}{2} - \sqrt{\frac{\frac{3}{4}}{6}}\right]}\sqrt{s(s+1)}$$

$$r = = \frac{a_o}{\left[1 - \frac{\sqrt{3/4}}{4\left(\frac{1}{2} - \frac{\sqrt{3/4}}{6}\right)}\right]} = 2.56\, a_o$$

The energy stored in the electric field is calculated as follows:

$$\frac{e^2}{8\pi\varepsilon_o r} = \frac{e^2}{8\pi\varepsilon_o 2.56 a_o} = 5.318 \text{ eV}$$

The field due to the outer shell electron changes the angular velocities of the inner shell electron; however, the magnetic field of the outer electron provides a central Lorentzian force which exactly balances the change in centripetal force due to the change in angular velocity. Thus, the radius of the inner shell is unchanged. Consequently, the electric energy of the inner shell is unchanged upon ionization. However, the outer field changes the magnetic moments of the inner shell electrons. The change per electron is given by Purcell as follows:

$$B_m = \frac{-e^2 r_1^2}{4\mu} B \qquad B = \frac{\mu_o e\hbar}{\mu r_2^3}$$

where r_1 is the radius of the inner shell and r_2 is the radius of the outer shell.

$$B_m = \frac{e^2 r_1^2}{4\mu}\frac{\mu_o e\hbar}{\mu r_2^3}$$

$$\frac{\mu_o e^2}{\mu r_2} = \sqrt{s(s+1)}$$

$$B_m = \frac{e\hbar}{4\mu}\frac{r_1^2}{r_2^2}\sqrt{s(s+1)} \qquad \mu_B = \frac{e\hbar}{2\mu}$$

$$\frac{B_m}{\mu_B} = \frac{e\hbar/4\mu}{e\hbar/2\mu}\frac{r_1^2}{r_2^2}\sqrt{s(s+1)} = \frac{1}{2}\frac{r_1^2}{r_2^2}\sqrt{s(s+1)}$$

$$= \frac{\frac{1}{2}\left[a_o\left[\frac{1}{2} - \frac{\sqrt{\frac{3}{4}}}{6}\right]\right]^2 \sqrt{3/4}}{\frac{a_o}{\left[1 - \frac{\sqrt{3/4}}{4\left(\frac{1}{2} - \frac{\sqrt{3/4}}{6}\right)}\right]^2}}$$

Multiply the result by two because there are two electrons.

$$= \sqrt{3/4}\frac{(0.3556)^2}{(2.555)^2}$$

$$= 0.0167$$

We add one and square to get the fractional change in the magnetic energy of the inner shell.(because the energy stored in the magnetic field is proportional to the magnetic field strength squared).

$(1.0167)^2 = 1.0338$

Thus, the change in magnetic energy of the inner shell is 3.382% which is given by:

2.543 eV (0.3382) = .0860 eV

(Where the magnetic energy of lithium$^+$ appears in Table II.)

$E_{ionization}$ = .0860 eV + 5.318 eV = 5.4038 eV

The calculated ionization energy without relativistic correction is 5.40 eV.

The experimental ionization energy is 5.392 eV.

Energy due to Spin Nuclear Interactions

If the magnetic quantum number of the nucleus is greater than 0, the nucleus has a magnetic moment and the magnetic field of the electron can interact with the nuclear moment. This interaction is an important parameter for structural determinations by electron paramagnetic resonance spectroscopy and Mossbauer spectroscopy. The energy of interaction is given as follows:

$E = \mu_n \cdot B$, where μ_n is the nuclear moment and B is the magnetic flux. In the case of an electron, it can be seen from Figure 2 that the flux of an electron at the nucleus is uniform and is given in Appendix IV as follows:

$$B = \frac{\mu_o e\hbar}{\mu r^3}\left(\hat{i}_r \cos\theta - \hat{i}_\sigma \sin\theta\right)$$

The magnetic moment of a proton is given as follows:

$$\mu p = \frac{e\hbar}{2mp}$$

where, m_p is the mass of the proton.

When the nuclear moment is aligned with the electron's field $\theta = 0$ and the energy is given as follows:

$$E = \frac{e\hbar}{2mp} \frac{\mu_o e\hbar}{\mu r^3}$$

These energies are small. For example the energy of spin-nuclear interactions for hydrogen are $1.98 * 10^{-5}$ eV.

The Nature of the Chemical Bond

The driving force of molecular bonding is the decrease in the energy stored in the electric fields of the participating atoms as a consequence of overlap of their Mills orbitals. (The magnetic stored energy is involved but is dominated by the electric stored energy.)

Consider two isolated hydrogen atoms that approach each other along the internuclear axis as shown in Figure 3. The electric field of each atom is zero for radial distance greater than a_o, the radius of the Mills orbital of the electron. As the Mills orbitals from one atom penetrates the space of the other, the electric field components add vectorially. The components parallel to the internuclear axis cancel, and the perpendicular components add positively. The latter components have a positive tangential projection onto the angular vectors of the Mills orbitals in the region of overlap.

The energy stored in the electric fields of the atoms decreases as the internuclear distance decreases; however, it reaches a minimum then increases rapidly as a function of the internuclear distance. The trajectory produces the classic potential well, and the internuclear distance is given the geometric calculation in Appendix V as $\sqrt{2}\, a_o = .748\text{Å}$ which is the exact experimental value. Thus, molecular bonding is demonstrated to result from interactions of the electric fields of atoms which minimizes the energy. Starting with the case of the hydrogen molecule of Appendix V, consider reducing the total charge of one of the Mills orbitals. The internuclear distance increases as the charge decreases. In the limit of no charge, the internuclear distance is $2a_o$. This

is apparent from the following argument, the addition of an infinitesimal amount of charge to the Mills orbital of zero charge produces an infinitesimal overlap due to an infinitesimal lowering of the total energy. Thus, the internuclear distance before the infinitesimal addition was $2a_o$ which is the exact experimentally measured distance for the H_{2+} molecule.

Furthermore, it can be shown that the diatomic molecule can be approximated by a harmonic oscillator with quantized energy levels given as follows:

$$E_{vib} = (n + 1/2)h\upsilon_o \qquad n = 0, 1, 2,...$$

$$\upsilon_o = \frac{1}{2\pi}\sqrt{\frac{k}{\mu}}$$

where μ is the reduced mass of the atoms, and k is the spring constant which is proportional to the bond strength; therefore, k is proportional to the gradient of the function of the bond energy as the internuclear distance changes.

It can also be shown that the rotational energies of a diatomic molecule are given as follows

$$E_{rot} = hcB(J + 1) \qquad J = 0, 1, 2,...$$

Selection Rules

The electrons which are described by Mills orbitals can absorb energy and achieve an excited state, and they can lose or emit energy and achieve a lower energy state. In the case electromagnetic radiation, energy flow is governed by Poynting's theorem

$$\nabla \cdot S = -j\omega\mu H \cdot H^* + j\omega\varepsilon E \cdot E^* - J^* \cdot E$$

where the parameters are as follows:
S is the power; the first term is the rate of change in the stored magnetic energy, the second term is the rate of change in the stored electric energy, and the third term is the dissipated power. For electromagnetic radiation, the ground state is the lowest energy state. The ground state is given by the balance of the centripetal and coulombic forces. For the hydrogen atom, the radius and energy appear in Table 2 as a_o and 13.6 eV, respectively. The boundary condition for Mills orbitals was given in the Mills Orbital Section as $2\pi r = n\lambda$ where $r = a_o$ for $n = 1$.

Thus, the absorption or emission of a photon by a hydrogen atom causes

the radius to change by an integer multiple of a_o. The energy of the photon is the difference in energy of the initial and final orbitals where the equation for the energies of the orbitals is given in the One Electron Atom Section. Photon absorption by an electron creates a standing wave of the photon's electric and magnetic fields inside of the Mills orbital. These fields are solutions to Laplace's equations in three dimensions which are spherical harmonic equations. The photon field exists as a standing wave where surface currents of the Mills orbital are generated by the said wave and are boundary conditions for its existence. The angular momentum and spin angular momentum of all Mills orbitals are given by

$$E_l = \hbar\sqrt{l(l+1)}$$

and

$$E_S = \hbar\sqrt{s(s+1)}$$

respectively.

The angular momentum is a vector; thus, it is apparent that the angular momentum can change by zero or ±1 during a photon absorption or emission event, a transition. Angular momentum must be conserved; therefore, the quantum of angular momentum is provided by the photon which carries the exact opposite quantum of angular momentum as that imparted to the Mills orbital. The standing wave of the photon is a traveling standing wave where the Mills orbital surface currents, induced by the wave, provide one quantum of angular momentum to the Mills orbital in the opposite direction to the angular direction of the traveling wave. Furthermore, angular momentum is also conserved if the wave does not travel. In this case, the photon wave can be considered as the superposition of two traveling waves rotating in opposite directions with the same angular velocity and is analogous to plane polarized light. Thus, the selection rules for a photon induced transition of Δm, $\Delta s = 0, \pm 1$ arise naturally (Δm is the change in angular momentum, and Δs is the change in spin angular momentum) where a change of zero is the nontraveling wave case and a change of 1 is the traveling wave case. This is totally consistent with experimentation which demonstrates these rules to be correct where the photon carries one or zero quantum of angular momentum. Consistently, a transition has a rise time and, consequently, a line width, as is the case in electrodynamics.

The standing photon wave has a nonzero electric field at the Mills orbital which has a radial component which combined with the induced surface currents provided by its tangential electric field cause the centripetal and central coulombic forces to be balanced at an integer multiple of a_o. Thus, the standing wave has an effective charge given by $\epsilon_o \hat{\mathcal{E}}_r$ which reduces the coulombic attraction of the nucleus. Because a photon can only reduce the coulombic attraction, the ground state, which contains no photon field, is the smallest radius possible for photon transitions. It will be shown in the Coulombic Annihilation Fusion Section that the resonant absorption of energy holes can shrink the radius by quantized fractions of a_o.

Effects of External Fields

External magnetic fields align magnetic moments (Bohr magnetons) of atoms for those with unpaired electrons, or external magnetic fields effect diamagnetic phenomenon in those materials that do not have unpaired electrons. Neither phenomenon affects the boundary conditions for nonradiation.

External electric fields cause a redistribution of the charge density of the Mills orbitals, the charge density functions, to create a dipole moment in the atom or molecule. This phenomenon is polarization. The orbital condition $2\pi r = n\lambda$ is not violated, so no radiation occurs.

Electrons can absorb photons from magnetic or electric fields to become ionized. This occurs readily in a conductor or superconductor. Mills orbitals of electrons are spherically symmetric. As photons are absorbed the radius expands from the ground state with radius r_1 to nr_1 where $n = 2, 3, \ldots$. As n goes to infinity the radius r goes to infinity and the Mills orbital becomes a plane wave. The boundary condition for a Mills orbital $2\pi r = n\lambda$ still applies; therefore, $\lambda = \frac{h}{p}$ .The plane wave nature of the ionized electron is confirmed by double slit experiments that demonstrate that the resulting interference pattern is consistent with the electron traveling through both slits simultaneously and possessing a wavelength

$$\lambda = \frac{h}{p}.$$

Metals have electrons as Mills orbitals which individually absorb energy in the form of a photon from applied magnetic or electric fields to

become ionized to produce individual plane waves which are scattered by phonons. There exists many electrons which can absorb the electric or magnetic energy to become ionized and propagate as plane waves through the material. In the case of superconductors, two electrons are ionized simultaneously and pair 180° out of phase as a zero phonon event to form Cooper pairs which have a low probability of being scattered as they propagate. Superconductors are described in detail in the Superconductor Section.

Superconductors

The Mills orbital of an electron is a spherical shell. The shell annihilates photons during absorption to trap them as standing waves inside the Mills orbital. The radius of the Mills orbital increases as the energy stored in the field of the photonic wave increases. Because the Mills orbital is a sphere, the orbital approaches a plane wave of charge density as the radius goes to infinity. Thus, an electron becomes a plane wave carrying a plane photon wave when it is ionized. Two electrons can be ionized simultaneously to create two traveling waves. If they are initially oppositely paired in terms of spin and angular momentum, then the two electrons with their accompanying photonic waves may add destructively. (180° out of phase, as plane waves when they are simultaneously ionized). This event occurs with no excitation of a phonon (lattice vibration). That is it must be a zero phonon event because phonons change the relative phases of the plane waves and exchange energy with the photonic fields.

These paired Mills orbital plane waves, which are 180° out of phase, carry the supercurrent in superconductors, and are known as Cooper pairs. They possess a low phonon interaction cross section for dephasing and breaking in the superconductor. Breaking the pairs requires the simultaneous absorption by the pair of anti-symmetric phonons. This is the boundary condition because Cooper pair creation was a zero phonon event; thus, anti-symmetric phonons must simultaneously be absorbed to break the Cooper pairs to conserve angular and linear momentum of the entire system-Cooper pair plus phonons (lattice distortions).

Thus, it is apparent that a superconductor with a high transition temperature is a material with the following properties:

1.) a large population of atoms with electrons which can

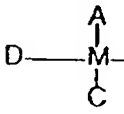
readily absorb energy from an electric or magnetic field to become ionized in such a fashion that they can participate in Cooper pair formation

2.) a low population of phonons at high temperatures

3.) a low population of phonons of sufficient energy to break Cooper pairs at high temperatures

4.) a low population or low probability ofopposite symmetry phonons of energy sufficient to break Cooper pairs.

Materials that contain atoms of transition elements satisfy condition 1. Materials which contain one of two dimensional lattices with strong bond energies satisfy conditions 2 and 3. Ceramics are materials of condition 2. Materials which contain one or two dimensional lattices with mixed valency or all different atoms in the unit well satisfy condition 4. The ideal unit cell is



, where M is a transition metal and A, B, C, and D are different atoms or different oxidation states of the same or different atoms. Perovskite superconductors such as (Ba, Sr, Y) x La_{2-x} CuO_4 are examples of materials which contain all of the said parameters.

Coulombic Annihilation Fusion

It was demonstrated in the Selection Rules Section that resonant photon absorption can only increase the radius of a Mills orbital. For resonant photon absorption, the ground state has the smallest radius possible. For the hydrogen, atom the radius of the ground state Mills orbital is given in Table 1 as a_o. This orbital contains no photonic waves, and the outward centripetal force and the inward coulombic force of the electron exactly balance. The relationship is as follows:

$$\frac{\mu v^2}{a_o} = \frac{e^2}{4\pi\varepsilon_o a_o} \qquad \text{where } v = \frac{\hbar}{\mu a_o}$$

It is apparent from this relationship that the radius would decrease if the velocity were somehow decreased. To decrease the velocity, energy must be removed which is equivalent to the absorption of an energy hole by the electron. When energy is removed the Mills orbital will decrease to another allowed state where the boundary condition, $2\pi r = n\lambda$, and the force balance is met.

Thus, it can be demonstrated, as appears in Appendix VI, that the absorption of an energy hole with concomitant shrinkage of the radius of the Mills orbital is a resonant process with quantum numbers. The resonance "shrinkage" energy given in Appendix VI for the hydrogen atom is n/2 27.21 eV where n = 2, 3,..., and the radius shrinkage is $a_o(\frac{1}{n_1} - \frac{1}{n_2})$ where n_1 is the quantum integer of the initial orbital and n_2 is the quantum integer of the final orbital of a radius shrinkage transition.

The electrons in deuterium atoms are described by Mills orbitals which satisfy the boundary condition $2\pi r = n\lambda$, and possess no space-time Fourier components synchronous with waves traveling at the speed of light; thus, they do not radiate. The electric field of the Mills orbital of a deuterium atom is that of a point charge at the origin for radial distances greater than the orbital radius. For these distances, the field of the Mills orbital exactly cancels the field of the proton which is also that of a point charge at the origin. The electric field of a Mills orbital is zero inside the orbital; thus, the electric field inside the orbital of the deuterium atom is the point charge field of the proton. It was demonstrated in the Nature of the Chemical Bond Section that chemical bonding was due to this feature of electric fields of Mills orbitals where the total energy of the electric fields of the participating atoms was minimized when the internuclear distance is $\sqrt{2}$ times the radius of the Mills orbital. And, this feature together with resonant shrinkage of the Mills orbitals is the basis of "cold fusion" of deuterium, Coulombic Annihilation Fusion, the present invention. Coulombic repulsions of the nuclei prevent them from approaching sufficiently for the strong nuclear force to dominate and for fusion to occur. However, outside of the Mills orbital of a deuterium atom there is no electric field; thus, for each of two deuterium atoms, when the Mills orbital is sufficiently decreased by the resonant absorption by energy holes, the internuclear distance of two deuterium atoms becomes the distance at which the attractive strong nuclear force dominates the repulsive coulombic force, and fusion of deuterium to helium and tritium occurs with the release of 931 MeV/amu. The mass change for fusion of deuterium is 0.03 amu; therefore 28 MeV/atom of energy is released.

It is demonstrated in Appendix VI that the radius of the Mills orbital

of the deuterium atom will decrease by $a_o\left(\frac{1}{n_1}-\frac{1}{n_2}\right)$ when an energy hole of energy equal to n/2 27.21 eV; n = 2, 3, 4,..., is resonantly absorbed. With continued resonance shrinkage-absorption of energy holes by the atom, the Mills orbital shrinks to small dimensions, and when approximately 100 KeV of energy holes have been absorbed the radius is sufficiently small that the deuterium atom will fuse with another atom of deuterium with a similar dimension of its Mills orbital.

A catalystic system to produce energy holes of 27.21 eV is a preferred embodiment of the present invention. For such a system the population of energy holes is not exhausted because they are regenerated.

Palladium $^{2+}$ and lithium^{+} is such a system. The catalytic cycle which affects the quantized decrease in the radius of the Mills orbital of the deuterium atom is as follows:

$$27.54\ eV + Li^{+} + Pd^{2+} + {}^2H\left[\frac{a_o}{p}\right] \rightarrow Li + Pd^{3+} + {}^2H\left[\frac{a_o}{(p+1)}\right] + [(p+1)^2 - n^2] \times 13.6\ eV$$

$$Li + Pd^{3+} = Li^{+} + Pd^{2+} + 27.54\ eV$$

Overall reaction

$$^2H\left[\frac{a_o}{p}\right] \rightarrow {}^2H\left[\frac{a_o}{(p+1)}\right] + [(p+1)^2 - p^2] \times 13.6\ eV$$

where p = 1, 2, 3,... .

The Palladium lithium system involves three species. The rate of the resonance shrinkage can be increased by reducing the number of species to two. Titanium, rubidium, or argon are effective catalysts. The catalytic reactions are as follows:

$$27.491\ eV + Ti^{2+} + {}^2H\left[\frac{a_o}{p}\right] \rightarrow Ti^{3+} + e^{-} + {}^2H\left[\frac{a_o}{(p+1)}\right] + [(p+1)^2 - p^2] \times 13.6\ eV$$

$$Ti^{3+} + e^{-} \rightarrow Ti^{2+} + 27.491\ eV$$

(8.8)

And, the overall reaction is

$$^2H\left[\frac{a_o}{p}\right] \rightarrow {}^2H\left[\frac{a_o}{(p+1)}\right] + [(p+1)^2 - p^2] \times 13.6\ eV$$

where the ionization energy, Eion, for Ti^{2+} is 27.491 eV; p is an integer

$$27.491\ eV + Rb^{+} + {}^2H\left[\frac{a_o}{p}\right] \rightarrow Rb^{2+} + e^{-} + {}^2H\left[\frac{a_o}{(p+1)}\right] + [(p+1)^2 - p^2] \times 13.6\ eV$$

$$Rb^{2+} + e^{-} \rightarrow Rb^{+} + 27.28\ eV$$

Overall reaction

$$^2H\left[\frac{a_o}{p}\right] \rightarrow {}^2H\left[\frac{a_o}{(p+1)}\right] + [(p+1)^2 - p^2] \times 13.6\ eV$$

where the ionization energy, Eion, for Rb^+ is 27.28 eV

$$27.63\ eV + Ar^+ + {}^2H\left[\frac{a_o}{p}\right] \rightarrow Ar^{2+} + e^- + {}^2H\left[\frac{a_o}{(p+1)}\right] + [(p+1)^2 - p^2] \times 13.6\ eV$$

$$Ar^{2+} + e^- \rightarrow Ar^+ + 27.63\ eV$$

5 Overall reaction

$$^2H\left[\frac{a_o}{p}\right] \rightarrow {}^2H\left[\frac{a_o}{(p+1)}\right] + [(p+1)^2 - p^2] \times 13.6\ eV$$

where the ionization energy, Eion, for Ar^+ is 27.629 eV.

The present invention comprises a source of energy holes of approximately 27 eV to resonantly shrink the Mills orbitals of deuterium atoms, including a source of said holes produced by further electrochemical reactions or chemical, photochemical, thermal, free radical, sonic, or nuclear reactions or inelastic particles, or photon scattering reactions. The closer the energy of the hole is to the quantum of 27.21 eV or the quanta of $\frac{n}{2}$ 27.21 eV; n = 2, 3, 4,..., the greater the rate of reaction because phonons ortranslational or rotational modes do not have to be simultaneously excited to match the resonant shrinkage energy. Table 3 is a table of ionization energies as given in Chemical Structure and Bonding, Rodger L. DeKock and Harry P. Gray, the Benjamim Cummings Publishing Company, Menlo Park, CA, (1980), pp. 76-77 which is incorporated by reference. Electrochemical couples with ionization energy differences of approximately 27 eV can catalyze the removal of energy from the electrons of deuterium and/or tritium atoms and molecules and catalyze cold fusion of deuterium and/or tritium.

Representative electrochemical couples which generate energy holes of approximately 27 eV appear in Table 4, and some catalytic couples comprising single elements which are cations, neutral, or anions and single molecules which are cations, anions, or neutral or combinations of the said species-reactants are also found in Table 4. For n = 2, the resonance energy is 27.21; for n = 16 the resonance energy is 217.68 eV; for n = 54, the resonance energy is 734.67 eV.

Table 4. Representative Electrochemical couples that catalytically produce energy holes of 27 eV to shrink deuterium atoms.

Electrochemical Couple	Ionization Energy	Energy Hole
Lu^{3+}	45.19	27.768
F^{+}	17.422	
Pb^{2+}	32.93	27.538
Li^{+}	5.392	
Ni^{2+}	35.17	27.3
Fe^{+}	7.46	
Ag^{2+}	34.83	27.37
Rh^{+}	7.46	
Zr^{3+}	34.34	27.241
Mo^{+}	7.099	
Nb^{3+}	38.3	27.863
Hg^{+}	10.437	
Cu^{2+}	36.83	27.605
Au^{+}	9.225	
Pb^{2+}	31.937	27.596
K^{+}	4.341	
Ge^{2+}	34.22	27.34
Nb^{+}	6.88	

Many others exist and are given in the above referenced Table 3 of ionization energies.

Table 4. (con't) Some representative single-ions capable of producing energy holes for shrinking deuterium atoms. The number following the atomic symbol, (n), is the nth ionization energy of the atom. That is for example, Ti^{2+} + 27.49 eV = Ti^{3+} + e^-.

Catalytic Ion	n	nth Ionization Energy
Al 2+	3	28.45
Ar 1+	2	27.63
Ti 2+	3	27.49
As 2+	3	28.35
Rb 1+	2	27.28
Mo 2+	3	27.16
Ru 2+	3	28.47
In 2+	3	28.03
Te 2+	3	27.96

Table 4. (con't) Some representative two-ion couples capable of producing energy holes for shrinking deuterium atoms. The number following the ion, (n), is the nth ionization energy of the atom. That is for example, Pd^{2+} + 32.93 eV = Pd^{3+} + e^- and Li^+ + e^- = Li + 5.39 eV.

Atom Oxidized	n	nth Ionization Energy (eV)	Atom Reduced	n	nth Ionization Energy (eV)	Energy Hole (eV)
Ne 1 +	2	40.96	H 1 +	1	13.60	27.36
Ar 2 +	3	40.74	H 1 +	1	13.60	27.14
Sn 3 +	4	40.73	H 1 +	1	13.60	27.14
Pm 3 +	4	41.10	H 1 +	1	13.60	27.50
Sm 3 +	4	41.40	H 1 +	1	13.60	27.80
Dy 3 +	4	41.50	H 1 +	1	13.60	27.90
Kr 3 +	4	52.50	He 1 +	1	24.59	27.91
Rb 3 +	4	52.60	He 1 +	1	24.59	28.01
K 4 +	5	82.66	He 2 +	2	54.42	28.24
Zn 4 +	5	82.60	He 2 +	2	54.42	28.18
Se 5 +	6	81.70	He 2 +	2	54.42	27.28
He 1 +	2	54.42	Rb 2 +	2	27.28	27.14

Zr 4 +	5	81.50	He 2 +	2	54.42	27.08
He 1 +	2	54.42	Mo 3 +	3	27.16	27.26
Si 2 +	3	33.49	Li 1 +	1	5.39	28.10
Mn 2 +	3	33.67	Li 1 +	1	5.39	28.27
Co 2 +	3	33.50	Li 1 +	1	5.39	28.11
Pd 2 +	3	32.93	Li 1 +	1	5.39	27.54
I 2 +	3	33.00	Li 1 +	1	5.39	27.61
Hf 3 +	4	33.33	Li 1 +	1	5.39	27.94
Li 1 +	2	75.64	C 3 +	3	47.89	27.75
Li 1 +	2	75.64	N 3 +	3	47.45	28.19
Li 1 +	2	75.64	Na 2 +	2	47.29	28.35
Li 1 +	2	75.64	S 4 +	4	47.30	28.34
Cu 5 +	6	103.00	Li 2 +	2	75.64	27.36
Li 1 +	2	75.64	Br 4 +	4	47.30	28.34
Br 6 +	7	103.00	Li 2 +	2	75.64	27.36
V 6 +	7	150.17	Li 3 +	3	122.45	27.72
Li 2 +	3	122.45	Mn 6 +	6	95.00	27.45
Cu 2 +	3	36.83	Be 1 +	1	9.32	27.51
Kr 2 +	3	36.95	Be 1 +	1	9.32	27.63
Cd 2 +	3	37.48	Be 1 +	1	9.32	28.16
Te 3 +	4	37.41	Be 1 +	1	9.32	28.09
Ce 3 +	4	36.76	Be 1 +	1	9.32	27.44
K 2 +	3	45.72	Be 2 +	2	18.21	27.51
V 3 +	4	46.71	Be 2 +	2	18.21	28.50
Ge 3 +	4	45.71	Be 2 +	2	18.21	27.50
Mo 3 +	4	46.40	Be 2 +	2	18.21	28.19
Bi 3 +	4	45.30	Be 2 +	2	18.21	27.09
Be 2 +	3	153.89	Ne 5 +	5	126.21	27.68
Be 2 +	3	153.89	Kr 8 +	8	126.00	27.89
Be 2 +	3	153.89	Mo 7 +	7	126.80	27.09
Be 3 +	4	217.71	Al 6 +	6	190.47	27.24
Br 2 +	3	36.00	B 1 +	1	8.30	27.70
Ce 3 +	4	36.76	B 1 +	1	8.30	28.46
Cl 3 +	4	53.46	B 2 +	2	25.15	28.31
Kr 3 +	4	52.50	B 2 +	2	25.15	27.35
Rb 3 +	4	52.60	B 2 +	2	25.15	27.45

	B 2 +	3	37.93	P 1 +	1	10.49	27.44
	P 4 +	5	65.02	B 3 +	3	37.93	27.09
	B 2 +	3	37.93	S 1 +	1	10.36	27.57
	V 4 +	5	65.23	B 3 +	3	37.93	27.30
5	B 2 +	3	37.93	As 1 +	1	9.81	28.12
	B 2 +	3	37.93	Se 1 +	1	9.75	28.18
	B 2 +	3	37.93	I 1 +	1	10.45	27.48
	B 2 +	3	37.93	Ba 2 +	2	10.00	27.93
	B 2 +	3	37.93	Ce 2 +	2	10.85	27.08
10	B 2 +	3	37.93	Pr 2 +	2	10.55	27.38
	B 2 +	3	37.93	Nd 2 +	2	10.73	27.20
	B 2 +	3	37.93	Pm 2 +	2	10.90	27.03
	B 2 +	3	37.93	Hg 1 +	1	10.44	27.49
	B 2 +	3	37.93	Rn 1 +	1	10.75	27.18
15	B 2 +	3	37.93	Ra 2 +	2	10.15	27.78
	Cl 2 +	3	39.61	C 1 +	1	11.26	28.35
	Zn 2 +	3	39.72	C 1 +	1	11.26	28.46
	Nb 3 +	4	38.30	C 1 +	1	11.26	27.04
	Pr 3 +	4	38.98	C 1 +	1	11.26	27.72
20	Kr 3 +	4	52.50	C 2 +	2	24.38	28.12
	Rb 3 +	4	52.60	C 2 +	2	24.38	28.22
	C 2 +	3	47.89	P 2 +	2	19.73	28.16
	Ar 4 +	5	75.02	C 3 +	3	47.89	27.13
	Fe 4 +	5	75.00	C 3 +	3	47.89	27.11
25	Ni 4 +	5	75.50	C 3 +	3	47.89	27.61
	C 2 +	3	47.89	Cu 2 +	2	20.29	27.60
	C 2 +	3	47.89	Ga 2 +	2	20.51	27.38
	C 2 +	3	47.89	Y 3 +	3	20.52	27.37
	C 2 +	3	47.89	Pd 2 +	2	19.43	28.46
30	C 2 +	3	47.89	Ce 3 +	3	20.20	27.69
	C 2 +	3	47.89	Gd 3 +	3	20.63	27.26
	C 2 +	3	47.89	Au 2 +	2	20.50	27.39
	C 2 +	3	47.89	Tl 2 +	2	20.43	27.46
	Sc 4 +	5	91.66	C 4 +	4	64.49	27.17
35	C 3 +	4	64.49	Cu 3 +	3	36.83	27.66
	C 3 +	4	64.49	Br 3 +	3	36.00	28.49

	C 3 +	4	64.49	Kr 3 +	3	36.95	27.54
	C 3 +	4	64.49	Cd 3 +	3	37.48	27.01
	C 3 +	4	64.49	Te 4 +	4	37.41	27.08
	C 3 +	4	64.49	Ce 4 +	4	36.76	27.73
5	Se 3 +	4	42.94	N 1 +	1	14.53	28.41
	Eu 3 +	4	42.60	N 1 +	1	14.53	28.07
	Ho 3 +	4	42.50	N 1 +	1	14.53	27.97
	Er 3 +	4	42.60	N 1 +	1	14.53	28.07
	Tm 3 +	4	42.70	N 1 +	1	14.53	28.17
10	Pb 3 +	4	42.32	N 1 +	1	14.53	27.79
	Sr 3 +	4	57.00	N 2 +	2	29.60	27.40
	N 2 +	3	47.45	P 2 +	2	19.73	27.72
	Ar 4 +	5	75.02	N 3 +	3	47.45	27.57
	Fe 4 +	5	75.00	N 3 +	3	47.45	27.55
15	Ni 4 +	5	75.50	N 3 +	3	47.45	28.05
	N 2 +	3	47.45	Cu 2 +	2	20.29	27.16
	N 2 +	3	47.45	Pd 2 +	2	19.43	28.02
	N 2 +	3	47.45	I 2 +	2	19.13	28.32
	N 2 +	3	47.45	La 3 +	3	19.18	28.27
20	N 2 +	3	47.45	Ce 3 +	3	20.20	27.25
	N 2 +	3	47.45	Tl 2 +	2	20.43	27.02
	N 3 +	4	77.47	Cr 4 +	4	49.10	28.37
	N 3 +	4	77.47	As 4 +	4	50.13	27.34
	N 3 +	4	77.47	La 4 +	4	49.95	27.52
25	Ne 4 +	5	126.21	N 5 +	5	97.89	28.32
	Fe 6 +	7	125.00	N 5 +	5	97.89	27.11
	Kr 7 +	8	126.00	N 5 +	5	97.89	28.11
	Nb 6 +	7	125.00	N 5 +	5	97.89	27.11
	N 4 +	5	97.89	Te 6 +	6	70.70	27.19
30	Ne 1 +	2	40.96	O 1 +	1	13.62	27.34
	Ar 2 +	3	40.74	O 1 +	1	13.62	27.12
	Sn 3 +	4	40.73	O 1 +	1	13.62	27.12
	Pm 3 +	4	41.10	O 1 +	1	13.62	27.48
	Sm 3 +	4	41.40	O 1 +	1	13.62	27.78
35	Dy 3 +	4	41.50	O 1 +	1	13.62	27.88
	F 2 +	3	62.71	O 2 +	2	35.12	27.59

Ne 2 +	3	63.45	O 2 +	2	35.12	28.33
O 1 +	2	35.12	Mg 1 +	1	7.65	27.47
O 1 +	2	35.12	Ti 1 +	1	6.82	28.30
O 1 +	2	35.12	V 1 +	1	6.74	28.38
O 1 +	2	35.12	Cr 1 +	1	6.77	28.35
O 1 +	2	35.12	Mn 1 +	1	7.43	27.68
O 1 +	2	35.12	Fe 1 +	1	7.87	27.25
O 1 +	2	35.12	Co 1 +	1	7.86	27.26
O 1 +	2	35.12	Ni 1 +	1	7.64	27.48
O 1 +	2	35.12	Cu 1 +	1	7.73	27.39
O 1 +	2	35.12	Ge 1 +	1	7.90	27.22
O 1 +	2	35.12	Zr 1 +	1	6.84	28.28
O 1 +	2	35.12	Nb 1 +	1	6.88	28.24
O 1 +	2	35.12	Mo 1 +	1	7.10	28.02
O 1 +	2	35.12	Tc 1 +	1	7.28	27.84
O 1 +	2	35.12	Ru 1 +	1	7.37	27.75
O 1 +	2	35.12	Rh 1 +	1	7.46	27.66
O 1 +	2	35.12	Ag 1 +	1	7.58	27.54
O 1 +	2	35.12	Sn 1 +	1	7.34	27.77
O 1 +	2	35.12	Ta 1 +	1	7.89	27.23
O 1 +	2	35.12	W 1 +	1	7.98	27.14
O 1 +	2	35.12	Re 1 +	1	7.88	27.24
O 1 +	2	35.12	Pb 1 +	1	7.42	27.70
O 1 +	2	35.12	Bi 1 +	1	7.29	27.83
O 2 +	3	54.93	Ar 2 +	2	27.63	27.30
K 4 +	5	82.66	O 3 +	3	54.93	27.73
O 2 +	3	54.93	Ti 3 +	3	27.49	27.44
Zn 4 +	5	82.60	O 3 +	3	54.93	27.67
O 2 +	3	54.93	Rb 2 +	2	27.28	27.65
O 2 +	3	54.93	Mo 3 +	3	27.16	27.77
O 3 +	4	77.41	Cr 4 +	4	49.10	28.31
O 3 +	4	77.41	As 4 +	4	50.13	27.28
O 3 +	4	77.41	La 4 +	4	49.95	27.46
Mg 4 +	5	141.26	O 5 +	5	113.90	27.36
O 5 +	6	138.12	Sc 6 +	6	111.10	27.02
Cu 7 +	8	166.00	O 6 +	6	138.12	27.88

O 5 +	6	138.12	Kr 7 +	7	111.00	27.12
Si 3 +	4	45.14	F 1 +	1	17.42	27.72
K 2 +	3	45.72	F 1 +	1	17.42	28.30
Ge 3 +	4	45.71	F 1 +	1	17.42	28.29
Lu 3 +	4	45.19	F 1 +	1	17.42	27.77
Bi 3 +	4	45.30	F 1 +	1	17.42	27.88
F 2 +	3	62.71	F 2 +	2	34.97	27.74
Ne 2 +	3	63.45	F 2 +	2	34.97	28.48
F 1 +	2	34.97	Mg 1 +	1	7.65	27.32
F 1 +	2	34.97	Sc 1 +	1	6.54	28.43
F 1 +	2	34.97	Ti 1 +	1	6.82	28.15
F 1 +	2	34.97	V 1 +	1	6.74	28.23
F 1 +	2	34.97	Cr 1 +	1	6.77	28.20
F 1 +	2	34.97	Mn 1 +	1	7.43	27.54
F 1 +	2	34.97	Fe 1 +	1	7.87	27.10
F 1 +	2	34.97	Co 1 +	1	7.86	27.11
F 1 +	2	34.97	Ni 1 +	1	7.64	27.34
F 1 +	2	34.97	Cu 1 +	1	7.73	27.24
F 1 +	2	34.97	Ge 1 +	1	7.90	27.07
F 1 +	2	34.97	Zr 1 +	1	6.84	28.13
F 1 +	2	34.97	Nb 1 +	1	6.88	28.09
F 1 +	2	34.97	Mo 1 +	1	7.10	27.87
F 1 +	2	34.97	Tc 1 +	1	7.28	27.69
F 1 +	2	34.97	Ru 1 +	1	7.37	27.60
F 1 +	2	34.97	Rh 1 +	1	7.46	27.51
F 1 +	2	34.97	Ag 1 +	1	7.58	27.39
F 1 +	2	34.97	Sn 1	1	7.34	27.63
F 1 +	2	34.97	Hf 1 +	1	6.60	28.37
F 1 +	2	34.97	Ta 1 +	1	7.89	27.08
F 1 +	2	34.97	Re 1 +	1	7.88	27.09
F 1 +	2	34.97	Pb 1 +	1	7.42	27.55
F 1 +	2	34.97	Bi 1 +	1	7.29	27.68
F 2 +	3	62.71	F 2 +	2	34.97	27.74
F 2 +	3	62.71	S 3 +	3	34.83	27.88
Ar 5 +	6	91.01	F 3 +	3	62.71	28.30
Cr 5 +	6	90.56	F 3 +	3	62.71	27.85

F 2 +	3	62.71	Ni 3 +	3	35.17	27.54
F 2 +	3	62.71	Ge 3 +	3	34.22	28.49
Sr 5 +	6	90.80	F 3 +	3	62.71	28.09
F 2 +	3	62.71	Zr 4 +	4	34.34	28.37
F 2 +	3	62.71	Ag 3 +	3	34.83	27.88
F 4 +	5	114.24	F 4 +	4	87.14	27.10
Cl 6 +	7	114.19	F 4 +	4	87.14	27.06
F 3 +	4	87.14	Ar 4 +	4	59.81	27.33
F 3 +	4	87.14	Zn 4 +	4	59.40	27.74
F 3 +	4	87.14	Br 5 +	5	59.70	27.44
F 3 +	4	87.14	Te 5 +	5	58.75	28.39
F 4 +	5	114.24	F 4 +	4	87.14	27.10
Mg 4 +	5	141.26	F 5 +	5	114.24	27.02
F 6 +	7	185.18	F 6 +	6	157.16	28.02
Cr 7 +	8	184.70	F 6 +	6	157.16	27.54
F 5 +	6	157.16	Co 7 +	7	129.00	28.16
F 5 +	6	157.16	Y 8 +	8	129.00	28.16
F 6 +	7	185.18	F 6 +	6	157.16	28.02
F 6 +	7	185.18	Ne 6 +	6	157.93	27.25
F 6 +	7	185.18	Co 8 +	8	157.00	28.18
Cr 3 +	4	49.10	Ne 1 +	1	21.56	27.54
La 3 +	4	49.95	Ne 1 +	1	21.56	28.39
Ne 1 +	2	40.96	Cl 1 +	1	12.97	28.00
Ne 1 +	2	40.96	Sc 2 +	2	12.80	28.16
Ne 1 +	2	40.96	Ti 2 +	2	13.58	27.38
Cr 4 +	5	69.30	Ne 2 +	2	40.96	28.34
Se 4 +	5	68.30	Ne 2 +	2	40.96	27.34
Ne 1 +	2	40.96	Zr 2 +	2	13.13	27.83
Mo 5 +	6	68.00	Ne 2 +	2	40.96	27.04
Ne 1 +	2	40.96	Lu 2 +	2	13.90	27.06
Pb 4 +	5	68.80	Ne 2 +	2	40.96	27.84
Ar 5 +	6	91.01	Ne 3 +	3	63.45	27.56
Sc 4 +	5	91.66	Ne 3 +	3	63.45	28.21
Cr 5 +	6	90.56	Ne 3 +	3	63.45	27.11
Ne 2 +	3	63.45	Ni 3 +	3	35.17	28.28
Ne 2 +	3	63.45	Br 3 +	3	36.00	27.45

	Sr 5 +	6	90.80	Ne 3 +	3	63.45	27.35
	Ar 6 +	7	124.32	Ne 4 +	4	97.11	27.21
	Ne 3 +	4	97.11	Cr 5 +	5	69.30	27.81
	Fe 6 +	7	125.00	Ne 4 +	4	97.11	27.89
5	Nb 6 +	7	125.00	Ne 4 +	4	97.11	27.89
	Ne 3 +	4	97.11	Pb 5 +	5	68.80	28.31
	Ne 4 +	5	126.21	Na 4 +	4	98.91	27.30
	Al 4 +	5	153.71	Ne 5 +	5	126.21	27.50
	Ne 4 +	5	126.21	Fe 6 +	6	99.00	27.21
10	Ne 4 +	5	126.21	Rb 7 +	7	99.20	27.01
	Si 2 +	3	33.49	Na 1 +	1	5.14	28.35
	Co 2 +	3	33.50	Na 1 +	1	5.14	28.36
	Pd 2 +	3	32.93	Na 1 +	1	5.14	27.79
	I 2 +	3	33.00	Na 1 +	1	5.14	27.86
15	Hf 3 +	4	33.33	Na 1 +	1	5.14	28.19
	Na 1 +	2	47.29	Al 2 +	2	18.83	28.46
	Na 1 +	2	47.29	P 2 +	2	19.73	27.56
	Ar 4 +	5	75.02	Na 2 +	2	47.29	27.73
	Fe 4 +	5	75.00	Na 2 +	2	47.29	27.71
20	Ni 4 +	5	75.50	Na 2 +	2	47.29	28.21
	Na 1 +	2	47.29	Pd 2 +	2	19.43	27.86
	Na 1 +	2	47.29	In 2 +	2	18.87	28.42
	Na 1 +	2	47.29	I 2 +	2	19.13	28.15
	Na 1 +	2	47.29	La 3 +	3	19.18	28.11
25	Na 1 +	2	47.29	Ce 3 +	3	20.20	27.09
	Na 3 +	4	98.91	Na 3 +	3	71.64	27.27
	K 5 +	6	100.00	Na 3 +	3	71.64	28.36
	Na 2 +	3	71.64	Ti 4 +	4	43.27	28.37
	Ti 4 +	5	99.22	Na 3 +	3	71.64	27.58
30	Fe 5 +	6	99.00	Na 3 +	3	71.64	27.36
	Rb 6 +	7	99.20	Na 3 +	3	71.64	27.56
	Na 2 +	3	71.64	Sr 3 +	3	43.60	28.04
	Na 2 +	3	71.64	Sb 4 +	4	44.20	27.44
	Na 2 +	3	71.64	Gd 4 +	4	44.00	27.64
35	Na 2 +	3	71.64	Yb 4 +	4	43.70	27.94
	Na 3 +	4	98.91	Na 3 +	3	71.64	27.27

Kr 7 +	8	126.00	Na 4 +	4	98.91	27.09
Na 3 +	4	98.91	Rb 5 +	5	71.00	27.91
Na 3 +	4	98.91	Sr 5 +	5	71.60	27.31
Mo 6 +	7	126.80	Na 4 +	4	98.91	27.89
Na 3 +	4	98.91	Te 6 +	6	70.70	28.21
Si 4 +	5	166.77	Na 5 +	5	138.39	28.38
Na 4 +	5	138.39	Sc 6 +	6	111.10	27.29
Cu 7 +	8	166.00	Na 5 +	5	138.39	27.61
Na 4 +	5	138.39	Kr 7 +	7	111.00	27.39
S 2 +	3	34.83	Mg 1 +	1	7.65	27.18
Ni 2 +	3	35.17	Mg 1 +	1	7.65	27.52
Br 2 +	3	36.00	Mg 1 +	1	7.65	28.35
Ag 2 +	3	34.83	Mg 1 +	1	7.65	27.18
Ti 3 +	4	43.27	Mg 2 +	2	15.03	28.23
Se 3 +	4	42.94	Mg 2 +	2	15.03	27.91
Eu 3 +	4	42.60	Mg 2 +	2	15.03	27.56
Ho 3 +	4	42.50	Mg 2 +	2	15.03	27.47
Er 3 +	4	42.60	Mg 2 +	2	15.03	27.56
Tm 3 +	4	42.70	Mg 2 +	2	15.03	27.67
Pb 3 +	4	42.32	Mg 2 +	2	15.03	27.28
Ni 5 +	6	108.00	Mg 3 +	3	80.14	27.86
Zn 5 +	6	108.00	Mg 3 +	3	80.14	27.86
Mg 2 +	3	80.14	Kr 4 +	4	52.50	27.64
Mg 2 +	3	80.14	Rb 4 +	4	52.60	27.54
Sb 5 +	6	108.00	Mg 3 +	3	80.14	27.86
Mg 3 +	4	109.24	Se 6 +	6	81.70	27.54
Mg 3 +	4	109.24	Zr 5 +	5	81.50	27.74
Te 6 +	7	137.00	Mg 4 +	4	109.24	27.76
Mg 4 +	5	141.26	Cl 7 +	7	114.19	27.07
Ti 7 +	8	168.50	Mg 5 +	5	141.26	27.24
Mg 5 +	6	186.50	Sc 8 +	8	158.70	27.80
Mg 6 +	7	224.94	Mn 8 +	8	196.46	28.48
Si 2 +	3	33.49	Al 1 +	1	5.99	27.51
Mn 2 +	3	33.67	Al 1 +	1	5.99	27.68
Co 2 +	3	33.50	Al 1 +	1	5.99	27.51
Ge 2 +	3	34.22	Al 1 +	1	5.99	28.23

Zr 3 +	4	34.34	Al 1 +	1	5.99	28.35
I 2 +	3	33.00	Al 1 +	1	5.99	27.01
Hf 3 +	4	33.33	Al 1 +	1	5.99	27.34
Hg 2 +	3	34.20	Al 1 +	1	5.99	28.21
S 3 +	4	47.30	Al 2 +	2	18.83	28.47
V 3 +	4	46.71	Al 2 +	2	18.83	27.88
Br 3 +	4	47.30	Al 2 +	2	18.83	28.47
Mo 3 +	4	46.40	Al 2 +	2	18.83	27.57
Sb 4 +	5	56.00	Al 3 +	3	28.45	27.55
Bi 4 +	5	56.00	Al 3 +	3	28.45	27.55
Ca 7 +	8	147.24	Al 4 +	4	119.99	27.25
Al 3 +	4	119.99	Sc 5 +	5	91.66	28.33
Al 4 +	5	153.71	Kr 8 +	8	126.00	27.71
Al 5 +	6	190.47	Ni 8 +	8	162.00	28.47
Ni 2 +	3	35.17	Si 1 +	1	8.15	27.02
Br 2 +	3	36.00	Si 1 +	1	8.15	27.85
Sr 2 +	3	43.60	Si 2 +	2	16.34	27.25
Sb 3 +	4	44.20	Si 2 +	2	16.34	27.86
Gd 3 +	4	44.00	Si 2 +	2	16.34	27.66
Yb 3 +	4	43.70	Si 2 +	2	16.34	27.36
K 3 +	4	60.91	Si 3 +	3	33.49	27.42
Si 2 +	3	33.49	Ca 1 +	1	6.11	27.38
Si 2 +	3	33.49	Ga 1 +	1	6.00	27.49
Si 2 +	3	33.49	Sr 1 +	1	5.70	27.80
Si 2 +	3	33.49	Y 1 +	1	6.38	27.11
Y 3 +	3	61.80	Si 3 +	3	33.49	28.31
Mo 4 +	5	61.20	Si 3 +	3	33.49	27.71
Si 2 +	3	33.49	In 1 +	1	5.79	27.71
Si 2 +	3	33.49	Ba 1 +	1	5.21	28.28
Si 2 +	3	33.49	La 1 +	1	5.58	27.92
Si 2 +	3	33.49	Ce 1 +	1	5.47	28.02
Si 2 +	3	33.49	Pr 1 +	1	5.42	28.07
Si 2 +	3	33.49	Nd 1 +	1	5.49	28.00
Si 2 +	3	33.49	Pm 1 +	1	5.55	27.94
Si 2 +	3	33.49	Sm 1 +	1	5.63	27.86
Si 2 +	3	33.49	Eu 1 +	1	5.67	27.83

	Si 2 +	3	33.49	Gd 1 +	1	6.14	27.35
	Si 2 +	3	33.49	Tb 1 +	1	5.85	27.64
	Si 2 +	3	33.49	Dy 1 +	1	5.93	27.57
	Si 2 +	3	33.49	Ho 1 +	1	6.02	27.47
5	Si 2 +	3	33.49	Er 1 +	1	6.10	27.39
	Si 2 +	3	33.49	Tm 1 +	1	6.18	27.31
	Si 2 +	3	33.49	Yb 1 +	1	6.25	27.24
	Si 2 +	3	33.49	Lu 1 +	1	5.43	28.07
	Si 2 +	3	33.49	Tl 1 +	1	6.11	27.38
10	Si 2 +	3	33.49	Ra 1 +	1	5.28	28.21
	Si 2 +	3	33.49	Ac 1 +	1	5.20	28.29
	Si 2 +	3	33.49	Th 1 +	1	6.10	27.39
	Si 2 +	3	33.49	Pa 1 +	1	5.90	27.59
	Si 2 +	3	33.49	U 1 +	1	6.05	27.44
15	Si 2 +	3	33.49	Np 1 +	1	6.20	27.29
	Si 2 +	3	33.49	Pu 1 +	1	6.06	27.43
	Si 2 +	3	33.49	Am 1 +	1	5.99	27.50
	Si 2 +	3	33.49	Cm 1 +	1	6.02	27.47
	Si 2 +	3	33.49	Bk 1 +	1	6.23	27.26
20	Si 2 +	3	33.49	Cf 1 +	1	6.30	27.19
	Si 2 +	3	33.49	Es 1 +	1	6.42	27.07
	S 4 +	5	72.68	Si 4 +	4	45.14	27.54
	Sc 3 +	4	73.47	Si 4 +	4	45.14	28.33
	Mn 4 +	5	72.40	Si 4 +	4	45.14	27.26
25	Si 3 +	4	45.14	Co 2 +	2	17.06	28.08
	Si 3 +	4	45.14	Zn 2 +	2	17.96	27.18
	Si 3 +	4	45.14	Ru 2 +	2	16.76	28.38
	Si 3 +	4	45.14	Rh 2 +	2	18.08	27.06
	Si 3 +	4	45.14	Cd 2 +	2	16.91	28.23
30	Sn 4 +	5	72.28	Si 4 +	4	45.14	27.14
	Si 3 +	4	45.14	Bi 2 +	2	16.69	28.45
	Si 4 +	5	166.77	Cu 7 +	7	139.00	27.77
	Nb 3 +	4	38.30	P 1 +	1	10.49	27.81
	Pr 3 +	4	38.98	P 1 +	1	10.49	28.49
35	S 3 +	4	47.30	P 2 +	2	19.73	27.57
	Br 3 +	4	47.30	P 2 +	2	19.73	27.57

	P 3 +	4	51.37	S 2 +	2	23.33	28.04
	P 3 +	4	51.37	Cl 2 +	2	23.81	27.56
	Co 4 +	5	79.50	P 4 +	4	51.37	28.13
	P 3 +	4	51.37	Kr 2 +	2	24.36	27.01
	Kr 5 +	6	78.50	P 4 +	4	51.37	27.13
	P 3 +	4	51.37	Zr 3 +	3	22.99	28.38
	P 3 +	4	51.37	Sm 3 +	3	23.40	27.97
	P 3 +	4	51.37	Tm 3 +	3	23.68	27.69
	P 3 +	4	51.37	Hf 3 +	3	23.30	28.07
	P 4 +	5	65.02	Cu 3 +	3	36.83	28.19
	Ge 4 +	5	93.50	P 5 +	5	65.02	28.48
	P 4 +	5	65.02	Kr 3 +	3	36.95	28.07
	Y 5 +	6	93.00	P 5 +	5	65.02	27.98
	P 4 +	5	65.02	Cd 3 +	3	37.48	27.54
	P 4 +	5	65.02	Te 4 +	4	37.41	27.61
	P 4 +	5	65.02	Ce 4 +	4	36.76	28.27
	P 5 +	6	220.43	Br 8 +	8	192.80	27.63
	P 7 +	8	309.41	S 7 +	7	280.93	28.48
	Nb 3 +	4	38.30	S 1 +	1	10.36	27.94
	Cd 2 +	3	37.48	S 1 +	1	10.36	27.12
	Te 3 +	4	37.41	S 1 +	1	10.36	27.05
	Ca 2 +	3	50.91	S 2 +	2	23.33	27.58
	Mn 3 +	4	51.20	S 2 +	2	23.33	27.87
	Co 3 +	4	51.30	S 2 +	2	23.33	27.97
	Nb 4 +	5	50.55	S 2 +	2	23.33	27.22
	S 2 +	3	34.83	Sc 1 +	1	6.54	28.29
	S 2 +	3	34.83	Ti 1 +	1	6.82	28.01
	S 2 +	3	34.83	V 1 +	1	6.74	28.09
	S 2 +	3	34.83	Cr 1 +	1	6.77	28.06
	S 2 +	3	34.83	Mn 1 +	1	7.43	27.40
	S 2 +	3	34.83	Ni 1 +	1	7.64	27.20
	S 2 +	3	34.83	Cu 1 +	1	7.73	27.10
	S 2 +	3	34.83	Y 1 +	1	6.38	28.45
	S 2 +	3	34.83	Zr 1 +	1	6.84	27.99
	S 2 +	3	34.83	Nb 1 +	1	6.88	27.95
	S 2 +	3	34.83	Mo 1 +	1	7.10	27.73

S 2+	3	34.83	Tc 1+	1	7.28	27.55
S 2+	3	34.83	Ru 1+	1	7.37	27.46
S 2+	3	34.83	Rh 1+	1	7.46	27.37
S 2+	3	34.83	Ag 1+	1	7.58	27.25
S 2+	3	34.83	Sn 1+	1	7.34	27.49
S 2+	3	34.83	Hf 1+	1	6.60	28.23
S 2+	3	34.83	Pb 1+	1	7.42	27.41
S 2+	3	34.83	Bi 1+	1	7.29	27.54
S 2+	3	34.83	Es 1+	1	6.42	28.41
Ar 4+	5	75.02	S 4+	4	47.30	27.72
Fe 4+	5	75.00	S 4+	4	47.30	27.70
Ni 4+	5	75.50	S 4+	4	47.30	28.20
S 3+	4	47.30	Cu 2+	2	20.29	27.01
S 3+	4	47.30	Pd 2+	2	19.43	27.87
S 3+	4	47.30	In 2+	2	18.87	28.43
S 3+	4	47.30	I 2+	2	19.13	28.17
S 3+	4	47.30	La 3+	3	19.18	28.12
S 3+	4	47.30	Ce 3+	3	20.20	27.10
K 5+	6	100.00	S 5+	5	72.68	27.32
S 4+	5	72.68	Sb 4+	4	44.20	28.48
S 4+	5	72.68	Lu 4+	4	45.19	27.49
S 4+	5	72.68	Bi 4+	4	45.30	27.38
S 5+	6	88.05	Ar 4+	4	59.81	28.24
S 5+	6	88.05	K 4+	4	60.91	27.14
S 5+	6	88.05	Br 5+	5	59.70	28.35
Y 6+	7	116.00	S 6+	6	88.05	27.95
Ar 2+	3	40.74	Cl 1+	1	12.97	27.77
Rb 2+	3	40.00	Cl 1+	1	12.97	27.03
Sn 3+	4	40.73	Cl 1+	1	12.97	27.77
Nd 3+	4	40.41	Cl 1+	1	12.97	27.44
Pm 3+	4	41.10	Cl 1+	1	12.97	28.13
Sm 3+	4	41.40	Cl 1+	1	12.97	28.43
Ca 2+	3	50.91	Cl 2+	2	23.81	27.10
Mn 3+	4	51.20	Cl 2+	2	23.81	27.39
Co 3+	4	51.30	Cl 2+	2	23.81	27.49
Cl 4+	5	67.80	Cl 3+	3	39.61	28.19

Cl 2 +	3	39.61	Ca 2 +	2	11.87	27.74
Ca 3 +	4	67.10	Cl 3 +	3	39.61	27.49
Cl 2 +	3	39.61	Br 1 +	1	11.81	27.80
Cl 2 +	3	39.61	Y 2 +	2	12.24	27.37
Mo 5 +	6	68.00	Cl 3 +	3	39.61	28.39
Cl 2 +	3	39.61	Xe 1 +	1	12.13	27.48
Cl 2 +	3	39.61	Eu 2 +	2	11.24	28.37
Cl 2 +	3	39.61	Gd 2 +	2	12.09	27.52
Cl 2 +	3	39.61	Tb 2 +	2	11.52	28.09
Cl 2 +	3	39.61	Dy 2 +	2	11.67	27.94
Cl 2 +	3	39.61	Ho 2 +	2	11.80	27.81
Cl 2 +	3	39.61	Er 2 +	2	11.93	27.68
Cl 2 +	3	39.61	Tm 2 +	2	12.05	27.56
Cl 2 +	3	39.61	Yb 2 +	2	12.18	27.43
Se 5 +	6	81.70	Cl 4 +	4	53.46	28.24
Zr 4 +	5	81.50	Cl 4 +	4	53.46	28.04
Cl 3 +	4	53.46	Nb 3 +	3	25.04	28.42
Cl 3 +	4	53.46	Sb 3 +	3	25.30	28.16
Cl 3 +	4	53.46	Cs 2 +	2	25.10	28.36
Cl 3 +	4	53.46	Yb 3 +	3	25.03	28.43
Cl 3 +	4	53.46	Bi 3 +	3	25.56	27.90
Cl 4 +	5	67.80	Cl 3 +	3	39.61	28.19
Cl 4 +	5	67.80	Ar 3 +	3	40.74	27.06
Mn 5 +	6	95.00	Cl 5 +	5	67.80	27.20
Cl 4 +	5	67.80	Zn 3 +	3	39.72	28.08
Cl 4 +	5	67.80	Rb 3 +	3	40.00	27.80
Cl 4 +	5	67.80	Sn 4 +	4	40.73	27.07
Cl 4 +	5	67.80	Nd 4 +	4	40.41	27.39
Cl 4 +	5	67.80	Tb 4 +	4	39.80	28.00
Ar 6 +	7	124.32	Cl 6 +	6	97.03	27.29
Cl 5 +	6	97.03	Cr 5 +	5	69.30	27.73
Fe 6 +	7	125.00	Cl 6 +	6	97.03	27.97
Nb 6 +	7	125.00	Cl 6 +	6	97.03	27.97
Cl 5 +	6	97.03	Pb 5 +	5	68.80	28.23
Ti 3 +	4	43.27	Ar 1 +	1	15.76	27.51
Se 3 +	4	42.94	Ar 1 +	1	15.76	27.19

	Te 4 +	5	58.75	K 2 +	2	31.63	27.13
	K 1 +	2	31.63	Cs 1 +	1	3.89	27.73
	Sc 3 +	4	73.47	K 3 +	3	45.72	27.75
	K 2 +	3	45.72	Ni 2 +	2	18.17	27.55
5	K 2 +	3	45.72	Zn 2 +	2	17.96	27.76
	K 2 +	3	45.72	As 2 +	2	18.63	27.09
	K 2 +	3	45.72	Rh 2 +	2	18.08	27.64
	K 2 +	3	45.72	Te 2 +	2	18.60	27.12
	K 2 +	3	45.72	Pt 2 +	2	18.56	27.16
10	K 3 +	4	60.91	Mn 3 +	3	33.67	27.24
	K 3 +	4	60.91	Co 3 +	3	33.50	27.41
	Br 5 +	6	88.60	K 4 +	4	60.91	27.69
	K 3 +	4	60.91	Pd 3 +	3	32.93	27.98
	K 3 +	4	60.91	I 3 +	3	33.00	27.91
15	K 3 +	4	60.91	Hf 4 +	4	33.33	27.58
	Bi 5 +	6	88.30	K 4 +	4	60.91	27.39
	Sc 5 +	6	111.10	K 5 +	5	82.66	28.44
	K 4 +	5	82.66	Fe 4 +	4	54.80	27.86
	K 4 +	5	82.66	Ni 4 +	4	54.90	27.76
20	K 4 +	5	82.66	Cu 4 +	4	55.20	27.46
	Kr 6 +	7	111.00	K 5 +	5	82.66	28.34
	Ca 6 +	7	127.70	K 6 +	6	100.00	27.70
	V 5 +	6	128.12	K 6 +	6	100.00	28.12
	K 5 +	6	100.00	Mn 5 +	5	72.40	27.60
25	As 5 +	6	127.60	K 6 +	6	100.00	27.60
	K 5 +	6	100.00	Sr 5 +	5	71.60	28.40
	K 5 +	6	100.00	Sn 5 +	5	72.28	27.72
	K 7 +	8	154.86	Ca 7 +	7	127.70	27.16
	K 7 +	8	154.86	As 6 +	6	127.60	27.26
30	K 7 +	8	154.86	Mo 7 +	7	126.80	28.06
	Mn 2 +	3	33.67	Ca 1 +	1	6.11	27.55
	Co 2	3	33.50	Ca 1 +	1	6.11	27.39
	Ge 2 +	3	34.22	Ca 1 +	1	6.11	28.11
	Zr 3 +	4	34.34	Ca 1 +	1	6.11	28.23
35	Hf 3 +	4	33.33	Ca 1 +	1	6.11	27.22
	Hg 2 +	3	34.20	Ca 1 +	1	6.11	28.09

	Zn 2 +	3	39.72	Ca 2 +	2	11.87	27.85
	Rb 2 +	3	40.00	Ca 2 +	2	11.87	28.13
	Pr 3 +	4	38.98	Ca 2 +	2	11.87	27.11
	Tb 3 +	4	39.80	Ca 2 +	2	11.87	27.93
5	Kr 5 +	6	78.50	Ca 3 +	3	50.91	27.59
	Ca 2 +	3	50.91	Zr 3 +	3	22.99	27.92
	Ca 2 +	3	50.91	Sm 3 +	3	23.40	27.51
	Ca 2 +	3	50.91	Dy 3 +	3	22.80	28.11
	Ca 2 +	3	50.91	Ho 3 +	3	22.84	28.07
10	Ca 2 +	3	50.91	Er 3 +	3	22.74	28.17
	Ca 2 +	3	50.91	Tm 3 +	3	23.68	27.23
	Ca 2 +	3	50.91	Hf 3 +	3	23.30	27.61
	Mn 5 +	6	95.00	Ca 4 +	4	67.10	27.90
	Ca 3 +	4	67.10	Zn 3 +	3	39.72	27.38
15	Ca 3 +	4	67.10	Rb 3 +	3	40.00	27.10
	Ca 3 +	4	67.10	Pr 4 +	4	38.98	28.12
	Ca 3 +	4	67.10	Tb 4 +	4	39.80	27.30
	Ca 4 +	5	84.41	Sr 4 +	4	57.00	27.41
	Ca 4 +	5	84.41	Sb 5 +	5	56.00	28.41
20	Ca 4 +	5	84.41	Bi 5 +	5	56.00	28.41
	Ca 5 +	6	108.78	Se 6 +	6	81.70	27.08
	Rb 7 +	8	136.00	Ca 6 +	6	108.78	27.22
	Ca 5 +	6	108.78	Zr 5 +	5	81.50	27.28
	Te 6 +	7	137.00	Ca 6 +	6	108.78	28.22
25	Ca 6 +	7	127.70	Ti 5 +	5	99.22	28.48
	Se 6 +	7	155.40	Ca 7 +	7	127.70	27.70
	Ca 7 +	8	147.24	Ti 6 +	6	119.36	27.88
	Ca 7 +	8	147.24	Mn 7 +	7	119.27	27.97
	Mn 2 +	3	33.67	Sc 1 +	1	6.54	27.13
30	Ge 2 +	3	34.22	Sc 1 +	1	6.54	27.68
	Zr 3 +	4	34.34	Sc 1 +	1	6.54	27.80
	Ag 2 +	3	34.83	Sc 1 +	1	6.54	28.29
	Hg 2 +	3	34.20	Sc 1 +	1	6.54	27.66
	Rb 2 +	3	40.00	Sc 2 +	2	12.80	27.20
35	Sn 3 +	4	40.73	Sc 2 +	2	12.80	27.93
	Nd 3 +	4	40.41	Sc 2 +	2	12.80	27.61

	Pm 3 +	4	41.10	Sc 2 +	2	12.80	28.30
	Kr 3 +	4	52.50	Sc 3 +	3	24.76	27.74
	Rb 3 +	4	52.60	Sc 3 +	3	24.76	27.84
	Sc 3 +	4	73.47	Ge 4 +	4	45.71	27.76
5	Sc 3 +	4	73.47	Mo 4 +	4	46.40	27.07
	Sc 3 +	4	73.47	Lu 4 +	4	45.19	28.28
	Sc 3 +	4	73.47	Bi 4 +	4	45.30	28.17
	Ti 5 +	6	119.36	Sc 5 +	5	91.66	27.70
	Mn 6 +	7	119.27	Sc 5 +	5	91.66	27.61
10	Sc 4 +	5	91.66	Ga 4 +	4	64.00	27.66
	Sc 4 +	5	91.66	As 5 +	5	63.63	28.03
	Cu 6 +	7	139.00	Sc 6 +	6	111.10	27.90
	Cu 7 +	8	166.00	Sc 7 +	7	138.00	28.00
	Ni 2 +	3	35.17	Ti 1 +	1	6.82	28.35
15	Ge 2 +	3	34.22	Ti 1 +	1	6.82	27.40
	Zr 3 +	4	34.34	Ti 1 +	1	6.82	27.52
	Ag 2 +	3	34.83	Ti 1 +	1	6.82	28.01
	Hg 2 +	3	34.20	Ti 1 +	1	6.82	27.38
	Sn 3 +	4	40.73	Ti 2 +	2	13.58	27.15
20	Pm 3 +	4	41.10	Ti 2 +	2	13.58	27.52
	Sm 3 +	4	41.40	Ti 2 +	2	13.58	27.82
	Dy 3 +	4	41.50	Ti 2 +	2	13.58	27.92
	Fe 3 +	4	54.80	Ti 3 +	3	27.49	27.31
	Ni 3 +	4	54.90	Ti 3 +	3	27.49	27.41
25	Cu 3 +	4	55.20	Ti 3 +	3	27.49	27.71
	Ti 3 +	4	43.27	Mn 2 +	2	15.64	27.63
	Ti 3 +	4	43.27	Fe 2 +	2	16.18	27.09
	Ti 3 +	4	43.27	Ge 2 +	2	15.93	27.33
	Rb 4 +	5	71.00	Ti 4 +	4	43.27	27.73
30	Sr 4 +	5	71.60	Ti 4 +	4	43.27	28.33
	Ti 3 +	4	43.27	Mo 2 +	2	16.15	27.12
	Ti 3 +	4	43.27	Tc 2 +	2	15.26	28.01
	Te 5 +	6	70.70	Ti 4 +	4	43.27	27.43
	Ti 3 +	4	43.27	Hf 2 +	2	14.90	28.37
35	Ti 3 +	4	43.27	Pb 2 +	2	15.03	28.23
	As 5 +	6	127.60	Ti 5 +	5	99.22	28.38

	Ti 4 +	5	99.22	Rb 5 +	5	71.00	28.22
	Ti 4 +	5	99.22	Sr 5 +	5	71.60	27.62
	Mo 6 +	7	126.80	Ti 5 +	5	99.22	27.58
	Ti 7 +	8	168.50	Ti 7 +	7	140.80	27.70
5	Ti 7 +	8	168.50	Ti 7 +	7	140.80	27.70
	Mn 7 +	8	196.46	Ti 8 +	8	168.50	27.96
	Ni 2 +	3	35.17	V 1 +	1	6.74	28.43
	Ge 2 +	3	34.22	V 1 +	1	6.74	27.48
	Zr 3 +	4	34.34	V 1 +	1	6.74	27.60
10	Ag 2 +	3	34.83	V 1 +	1	6.74	28.09
	Hg 2 +	3	34.20	V 1 +	1	6.74	27.46
	Se 3 +	4	42.94	V 2 +	2	14.65	28.29
	Eu 3 +	4	42.60	V 2 +	2	14.65	27.95
	Ho 3 +	4	42.50	V 2 +	2	14.65	27.85
15	Er 3 +	4	42.60	V 2 +	2	14.65	27.95
	Tm 3 +	4	42.70	V 2 +	2	14.65	28.05
	Pb 3 +	4	42.32	V 2 +	2	14.65	27.67
	Sr 3 +	4	57.00	V 3 +	3	29.31	27.69
	Fe 4 +	5	75.00	V 4 +	4	46.71	28.29
20	V 3 +	4	46.71	As 2 +	2	18.63	28.07
	V 3 +	4	46.71	Pd 2 +	2	19.43	27.28
	V 3 +	4	46.71	In 2 +	2	18.87	27.84
	V 3 +	4	46.71	Te 2 +	2	18.60	28.11
	V 3 +	4	46.71	I 2 +	2	19.13	27.58
25	V 3 +	4	46.71	La 3 +	3	19.18	27.53
	V 3 +	4	46.71	Pt 2 +	2	18.56	28.14
	V 3 +	4	46.71	Hg 2 +	2	18.76	27.95
	V 4 +	5	65.23	Cu 3 +	3	36.83	28.40
	Ge 4 +	5	93.50	V 5 +	5	65.23	28.27
30	V 4 +	5	65.23	Kr 3 +	3	36.95	28.28
	Y 5 +	6	93.00	V 5 +	5	65.23	27.77
	V 4 +	5	65.23	Cd 3 +	3	37.48	27.75
	V 4 +	5	65.23	Te 4 +	4	37.41	27.82
	V 4 +	5	65.23	Ce 4 +	4	36.76	28.47
35	Se 6 +	7	155.40	V 6 +	6	128.12	27.28
	V 6 +	7	150.17	Sr 8 +	8	122.30	27.87

Ni 2 +	3	35.17	Cr 1 +	1	6.77	28.40
Ge 2 +	3	34.22	Cr 1 +	1	6.77	27.45
Zr 3 +	4	34.34	Cr 1 +	1	6.77	27.57
Ag 2 +	3	34.83	Cr 1 +	1	6.77	28.06
Hg 2 +	3	34.20	Cr 1 +	1	6.77	27.43
Sr 2 +	3	43.60	Cr 2 +	2	16.50	27.10
Sb 3 +	4	44.20	Cr 2 +	2	16.50	27.70
Gd 3 +	4	44.00	Cr 2 +	2	16.50	27.50
Yb 3 +	4	43.70	Cr 2 +	2	16.50	27.20
Zn 3 +	4	59.40	Cr 3 +	3	30.96	28.44
Te 4 +	5	58.75	Cr 3 +	3	30.96	27.79
Cr 2 +	3	30.96	Cs 1 +	1	3.89	27.07
Cr 3 +	4	49.10	Se 2 +	2	21.19	27.91
Cr 3 +	4	49.10	Br 2 +	2	21.80	27.30
Y 4 +	5	77.00	Cr 4 +	4	49.10	27.90
Cr 3 +	4	49.10	Ag 2 +	2	21.49	27.61
Cr 3 +	4	49.10	Xe 2 +	2	21.21	27.89
Cr 3 +	4	49.10	Pr 3 +	3	21.62	27.48
Cr 3 +	4	49.10	Gd 3 +	3	20.63	28.47
Cr 3 +	4	49.10	Tb 3 +	3	21.91	27.19
Cr 3 +	4	49.10	Lu 3 +	3	20.96	28.14
Cr 4 +	5	69.30	Pm 4 +	4	41.10	28.20
Cr 4 +	5	69.30	Sm 4 +	4	41.40	27.90
Cr 4 +	5	69.30	Dy 4 +	4	41.50	27.80
Cr 6 +	7	161.10	Ni 7 +	7	133.00	28.10
Cr 6 +	7	161.10	Zn 7 +	7	134.00	27.10
Cr 7 +	8	184.70	Co 8 +	8	157.00	27.70
Ni 2 +	3	35.17	Mn 1 +	1	7.43	27.73
Ag 2 +	3	34.83	Mn 1 +	1	7.43	27.40
Se 3 +	4	42.94	Mn 2 +	2	15.64	27.30
Sr 2 +	3	43.60	Mn 2 +	2	15.64	27.96
Gd 3 +	4	44.00	Mn 2 +	2	15.64	28.36
Tm 3 +	4	42.70	Mn 2 +	2	15.64	27.06
Yb 3 +	4	43.70	Mn 2 +	2	15.64	28.06
Mn 2 +	3	33.67	Ga 1 +	1	6.00	27.67
Mn 2 +	3	33.67	Sr 1 +	1	5.70	27.97

	Mn 2 +	3	33.67	Y 1 +	1	6.38	27.29
	Y 3 +	4	61.80	Mn 3 +	3	33.67	28.13
	Mo 4 +	5	61.20	Mn 3 +	3	33.67	27.53
	Mn 2 +	3	33.67	In 1 +	1	5.79	27.88
5	Mn 2 +	3	33.67	Ba 1 +	1	5.21	28.45
	Mn 2 +	3	33.67	La 1 +	1	5.58	28.09
	Mn 2 +	3	33.67	Ce 1 +	1	5.47	28.20
	Mn 2 +	3	33.67	Pr 1 +	1	5.42	28.24
	Mn 2 +	3	33.67	Nd 1 +	1	5.49	28.18
10	Mn 2 +	3	33.67	Pm 1 +	1	5.55	28.11
	Mn 2 +	3	33.67	Sm 1 +	1	5.63	28.04
	Mn 2 +	3	33.67	Eu 1 +	1	5.67	28.00
	Mn 2 +	3	33.67	Gd 1 +	1	6.14	27.53
	Mn 2 +	3	33.67	Tb 1 +	1	5.85	27.82
15	Mn 2 +	3	33.67	Dy 1 +	1	5.93	27.74
	Mn 2 +	3	33.67	Ho 1 +	1	6.02	27.65
	Mn 2 +	3	33.67	Er 1 +	1	6.10	27.57
	Mn 2 +	3	33.67	Tm 1 +	1	6.18	27.48
	Mn 2 +	3	33.67	Yb 1 +	1	6.25	27.41
20	Mn 2 +	3	33.67	Lu 1 +	1	5.43	28.24
	Mn 2 +	3	33.67	Hf 1 +	1	6.60	27.07
	Mn 2 +	3	33.67	Tl 1 +	1	6.11	27.56
	Mn 2 +	3	33.67	Ra 1 +	1	5.28	28.39
	Mn 2 +	3	33.67	Ac 1 +	1	5.20	28.47
25	Mn 2 +	3	33.67	Th 1 +	1	6.10	27.57
	Mn 2 +	3	33.67	Pa 1 +	1	5.90	27.77
	Mn 2 +	3	33.67	U 1 +	1	6.05	27.62
	Mn 2 +	3	33.67	Np 1 +	1	6.20	27.47
	Mn 2 +	3	33.67	Pu 1 +	1	6.06	27.61
30	Mn 2 +	3	33.67	Am 1 +	1	5.99	27.68
	Mn 2 +	3	33.67	Cm 1 +	1	6.02	27.65
	Mn 2 +	3	33.67	Bk 1 +	1	6.23	27.44
	Mn 2 +	3	33.67	Cf 1 +	1	6.30	27.37
	Mn 2 +	3	33.67	Es 1 +	1	6.42	27.25
35	Co 4 +	5	79.50	Mn 4 +	4	51.20	28.30
	Kr 5 +	6	78.50	Mn 4 +	4	51.20	27.30

	Mn 3 +	4	51.20	Zr 3 +	3	22.99	28.21
	Mn 3 +	4	51.20	Sm 3 +	3	23.40	27.80
	Mn 3 +	4	51.20	Dy 3 +	3	22.80	28.40
	Mn 3 +	4	51.20	Ho 3 +	3	22.84	28.36
5	Mn 3 +	4	51.20	Er 3 +	3	22.74	28.46
	Mn 3 +	4	51.20	Tm 3 +	3	23.68	27.52
	Mn 3 +	4	51.20	Hf 3 +	3	23.30	27.90
	Mn 4 +	5	72.40	Sb 4 +	4	44.20	28.20
	Mn 4 +	5	72.40	Gd 4 +	4	44.00	28.40
10	Mn 4 +	5	72.40	Lu 4 +	4	45.19	27.21
	Mn 4 +	5	72.40	Bi 4 +	4	45.30	27.10
	Sr 7 +	8	122.30	Mn 6 +	6	95.00	27.30
	Mn 6 +	7	119.27	Sr 6 +	6	90.80	28.47
	Ni 2 +	3	35.17	Fe 1 +	1	7.87	27.30
15	Br 2 +	3	36.00	Fe 1 +	1	7.87	28.13
	Sr 2 +	3	43.60	Fe 2 +	2	16.18	27.42
	Sb 3 +	4	44.20	Fe 2 +	2	16.18	28.02
	Gd 3 +	4	44.00	Fe 2 +	2	16.18	27.82
	Yb 3 +	4	43.70	Fe 2 +	2	16.18	27.52
20	Te 4 +	5	58.75	Fe 3 +	3	30.65	28.10
	Zn 4 +	5	82.60	Fe 4 +	4	54.80	27.80
	Fe 3 +	4	54.80	Rb 2 +	2	27.28	27.52
	Fe 3 +	4	54.80	Mo 3 +	3	27.16	27.64
	Cu 5 +	6	103.00	Fe 5 +	5	75.00	28.00
25	Fe 4 +	5	75.00	Br 4 +	4	47.30	27.70
	Br 6 +	7	103.00	Fe 5 +	5	75.00	28.00
	Nb 5 +	6	102.60	Fe 5 +	5	75.00	27.60
	Fe 5 +	6	99.00	Rb 5 +	5	71.00	28.00
	Fe 5 +	6	99.00	Sr 5 +	5	71.60	27.40
30	Mo 6 +	7	126.80	Fe 6 +	6	99.00	27.80
	Fe 5 +	6	99.00	Te 6 +	6	70.70	28.30
	Mo 7 +	8	153.00	Fe 7 +	7	125.00	28.00
	Ni 2 +	3	35.17	Co 1 +	1	7.86	27.31
	Br 2 +	3	36.00	Co 1 +	1	7.86	28.14
35	Sb 3 +	4	44.20	Co 2 +	2	17.06	27.14
	Lu 3 +	4	45.19	Co 2 +	2	17.06	28.13

	Bi 3 +	4	45.30	Co 2 +	2	17.06	28.24
	Co 2 +	3	33.50	Ga 1 +	1	6.00	27.50
	Co 2 +	3	33.50	Sr 1 +	1	5.70	27.81
	Co 2 +	3	33.50	Y 1 +	1	6.38	27.12
5	Y 3 +	4	61.80	Co 3 +	3	33.50	28.30
	Mo 4 +	5	61.20	Co 3 +	3	33.50	27.70
	Co 2 +	3	33.50	In 1 +	1	5.79	27.71
	Co 2 +	3	33.50	Ba 1 +	1	5.21	28.29
	Co 2 +	3	33.50	La 1 +	1	5.58	27.92
10	Co 2 +	3	33.50	Ce 1 +	1	5.47	28.03
	Co 2 +	3	33.50	Pr 1 +	1	5.42	28.08
	Co 2 +	3	33.50	Nd 1 +	1	5.49	28.01
	Co 2 +	3	33.50	Pm 1 +	1	5.55	27.95
	Co 2 +	3	33.50	Sm 1 +	1	5.63	27.87
15	Co 2 +	3	33.50	Eu 1 +	1	5.67	27.83
	Co 2 +	3	33.50	Gd 1 +	1	6.14	27.36
	Co 2 +	3	33.50	Tb 1 +	1	5.85	27.65
	Co 2 +	3	33.50	Dy 1 +	1	5.93	27.57
	Co 2 +	3	33.50	Ho 1 +	1	6.02	27.48
20	Co 2 +	3	33.50	Er 1 +	1	6.10	27.40
	Co 2 +	3	33.50	Tm 1 +	1	6.18	27.32
	Co 2 +	3	33.50	Yb 1 +	1	6.25	27.25
	Co 2 +	3	33.50	Lu 1 +	1	5.43	28.07
	Co 2 +	3	33.50	Tl 1 +	1	6.11	27.39
25	Co 2 +	3	33.50	Ra 1 +	1	5.28	28.22
	Co 2 +	3	33.50	Ac 1 +	1	5.20	28.30
	Co 2 +	3	33.50	Th 1 +	1	6.10	27.40
	Co 2 +	3	33.50	Pa 1 +	1	5.90	27.60
	Co 2 +	3	33.50	U 1 +	1	6.05	27.45
30	Co 2 +	3	33.50	Np 1 +	1	6.20	27.30
	Co 2 +	3	33.50	Pu 1 +	1	6.06	27.44
	Co 2 +	3	33.50	Am 1 +	1	5.99	27.51
	Co 2 +	3	33.50	Cm 1 +	1	6.02	27.48
	Co 2 +	3	33.50	Bk 1 +	1	6.23	27.27
35	Co 2 +	3	33.50	Cf 1 +	1	6.30	27.20
	Co 2 +	3	33.50	Es 1 +	1	6.42	27.08

	Co 4 +	5	79.50	Co 4 +	4	51.30	28.20
	Kr 5 +	6	78.50	Co 4 +	4	51.30	27.20
	Co 3 +	4	51.30	Zr 3 +	3	22.99	28.31
	Co 3 +	4	51.30	Sm 3 +	3	23.40	27.90
5	Co 3 +	4	51.30	Ho 3 +	3	22.84	28.46
	Co 3 +	4	51.30	Tm 3 +	3	23.68	27.62
	Co 3 +	4	51.30	Hf 3 +	3	23.30	28.00
	Co 4 +	5	79.50	Co 4 +	4	51.30	28.20
	Co 7 +	8	157.00	Co 7 +	7	129.00	28.00
10	Co 7 +	8	157.00	Co 7 +	7	129.00	28.00
	Co 7 +	8	157.00	Y 8 +	8	129.00	28.00
	Ni 2 +	3	35.17	Ni 1 +	1	7.64	27.53
	Br 2 +	3	36.00	Ni 1 +	1	7.64	28.36
	Ag 2 +	3	34.83	Ni 1 +	1	7.64	27.20
15	Ge 3 +	4	45.71	Ni 2 +	2	18.17	27.54
	Mo 3 +	4	46.40	Ni 2 +	2	18.17	28.23
	Lu 3 +	4	45.19	Ni 2 +	2	18.17	27.02
	Bi 3 +	4	45.30	Ni 2 +	2	18.17	27.13
	Ni 2 +	3	35.17	Ni 1 +	1	7.64	27.53
20	Ni 2 +	3	35.17	Cu 1 +	1	7.73	27.44
	Ni 2 +	3	35.17	Ge 1 +	1	7.90	27.27
	As 4 +	5	63.63	Ni 3 +	3	35.17	28.46
	Ni 2 +	3	35.17	Zr 1 +	1	6.84	28.33
	Ni 2 +	3	35.17	Nb 1 +	1	6.88	28.29
25	Ni 2 +	3	35.17	Mo 1 +	1	7.10	28.07
	Ni 2 +	3	35.17	Tc 1 +	1	7.28	27.89
	Ni 2 +	3	35.17	Ru 1 +	1	7.37	27.80
	Ni 2 +	3	35.17	Rh 1 +	1	7.46	27.71
	Ni 2 +	3	35.17	Ag 1 +	1	7.58	27.59
30	Ni 2 +	3	35.17	Sn 1 +	1	7.34	27.83
	Ni 2 +	3	35.17	Ta 1 +	1	7.89	27.28
	Ni 2 +	3	35.17	W 1 +	1	7.98	27.19
	Ni 2 +	3	35.17	Re 1 +	1	7.88	27.29
	Ni 2 +	3	35.17	Pb 1 +	1	7.42	27.75
35	Ni 2 +	3	35.17	Bi 1 +	1	7.29	27.88
	Zn 4 +	5	82.60	Ni 4 +	4	54.90	27.70

Ni 3 +	4	54.90	Rb 2 +	2	27.28	27.62
Ni 3	4	54.90	Mo 3 +	3	27.16	27.74
Cu 5 +	6	103.00	Ni 5 +	5	75.50	27.50
Ni 4 +	5	75.50	Br 4 +	4	47.30	28.20
Br 6 +	7	103.00	Ni 5 +	5	75.50	27.50
Nb 5 +	6	102.60	Ni 5 +	5	75.50	27.10
Ni 5 +	6	108.00	Cu 5 +	5	79.90	28.10
Rb 7 +	8	136.00	Ni 6 +	6	108.00	28.00
Ni 7 +	8	162.00	Zn 7 +	7	134.00	28.00
Br 2 +	3	36.00	Cu 1 +	1	7.73	28.27
Ag 2 +	3	34.83	Cu 1 +	1	7.73	27.10
Br 3 +	4	47.30	Cu 2 +	2	20.29	27.01
Cu 2 +	3	36.83	Zn 1 +	1	9.39	27.44
Ga 3 +	4	64.00	Cu 3 +	3	36.83	27.17
Cu 2 +	3	36.83	As 1 +	1	9.81	27.02
Cu 2 +	3	36.83	Se 1 +	1	9.75	27.08
Kr 4 +	5	64.70	Cu 3 +	3	36.83	27.87
Cu 2 +	3	36.83	Pd 1 +	1	8.34	28.49
Cu 2 +	3	36.83	Cd 1 +	1	8.99	27.84
Cu 2 +	3	36.83	Sb 1 +	1	8.64	28.19
Cu 2 +	3	36.83	Te 1 +	1	9.01	27.82
Cu 2 +	3	36.83	Os 1 +	1	8.70	28.13
Cu 2 +	3	36.83	Ir 1 +	1	9.10	27.73
Cu 2 +	3	36.83	Pt 1 +	1	9.00	27.83
Cu 2 +	3	36.83	Au 1 +	1	9.23	27.61
Cu 2 +	3	36.83	Po 1 +	1	8.42	28.41
Zn 4 +	5	82.60	Cu 4 +	4	55.20	27.40
Cu 3 +	4	55.20	Rb 2 +	2	27.28	27.92
Cu 3 +	4	55.20	Mo 3 +	3	27.16	28.04
Cu 3 +	4	55.20	In 3 +	3	28.03	27.17
Cu 3 +	4	55.20	Te 3 +	3	27.96	27.24
Zn 5 +	6	108.00	Cu 5 +	5	79.90	28.10
Cu 4 +	5	79.90	Kr 4 +	4	52.50	27.40
Cu 4 +	5	79.90	Rb 4 +	4	52.60	27.30
Sb 5 +	6	108.00	Cu 5 +	5	79.90	28.10
Cu 6 +	7	139.00	Kr 7 +	7	111.00	28.00

Kr 2 +	3	36.95	Zn 1 +	1	9.39	27.56
Cd 2 +	3	37.48	Zn 1 +	1	9.39	28.09
Te 3 +	4	37.41	Zn 1 +	1	9.39	28.02
Ce 3 +	4	36.76	Zn 1 +	1	9.39	27.36
Ge 3 +	4	45.71	Zn 2 +	2	17.96	27.75
Mo 3 +	4	46.40	Zn 2 +	2	17.96	28.44
Lu 3 +	4	45.19	Zn 2 +	2	17.96	27.23
Bi 3 +	4	45.30	Zn 2 +	2	17.96	27.34
Zn 2 +	3	39.72	Br 1 +	1	11.81	27.91
Zn 2 +	3	39.72	Y 2 +	2	12.24	27.48
Mo 5 +	6	68.00	Zn 3 +	3	39.72	28.28
Zn 2 +	3	39.72	Xe 1 +	1	12.13	27.59
Zn 2 +	3	39.72	Eu 2 +	2	11.24	28.48
Zn 2 +	3	39.72	Gd 2 +	2	12.09	27.63
Zn 2 +	3	39.72	Tb 2 +	2	11.52	28.20
Zn 2 +	3	39.72	Dy 2 +	2	11.67	28.05
Zn 2 +	3	39.72	Ho 2 +	2	11.80	27.92
Zn 2 +	3	39.72	Er 2 +	2	11.93	27.79
Zn 2 +	3	39.72	Tm 2 +	2	12.05	27.67
Zn 2 +	3	39.72	Yb 2 +	2	12.18	27.54
Zn 3 +	4	59.40	Rh 3 +	3	31.06	28.34
Zn 3 +	4	59.40	Xe 3 +	3	32.10	27.30
Zn 3 +	4	59.40	Pb 3 +	3	31.94	27.46
Kr 6 +	7	111.00	Zn 5 +	5	82.60	28.40
Rb 7 +	8	136.00	Zn 6 +	6	108.00	28.00
Zn 6 +	7	134.00	Sr 7 +	7	106.00	28.00
Ge 2 +	3	34.22	Ga 1 +	1	6.00	28.22
Zr 3 +	4	34.34	Ga 1 +	1	6.00	28.34
I 2 +	3	33.00	Ga 1 +	1	6.00	27.00
Hf 3 +	4	33.33	Ga 1 +	1	6.00	27.33
Hg 2 +	3	34.20	Ga 1 +	1	6.00	28.20
Te 4 +	5	58.75	Ga 3 +	3	30.71	28.04
Ga 3 +	4	64.00	Br 3 +	3	36.00	28.00
Ga 3 +	4	64.00	Kr 3 +	3	36.95	27.05
Ga 3 +	4	64.00	Ce 4 +	4	36.76	27.24
Br 2 +	3	36.00	Ge 1 +	1	7.90	28.10

	Se 3 +	4	42.94	Ge 2 +	2	15.93	27.01
	Sr 2 +	3	43.60	Ge 2 +	2	15.93	27.67
	Sb 3 +	4	44.20	Ge 2 +	2	15.93	28.27
	Gd 3 +	4	44.00	Ge 2 +	2	15.93	28.07
5	Yb 3 +	4	43.70	Ge 2 +	2	15.93	27.77
	Ge 2 +	3	34.22	Y 1 +	1	6.38	27.84
	Y 3 +	4	61.80	Ge 3 +	3	34.22	27.58
	Ge 2 +	3	34.22	Zr 1 +	1	6.84	27.38
	Ge 2 +	3	34.22	Nb 1 +	1	6.88	27.34
10	Ge 2 +	3	34.22	Mo 1 +	1	7.10	27.12
	Ge 2 +	3	34.22	In 1 +	1	5.79	28.43
	Ge 2 +	3	34.22	Gd 1 +	1	6.14	28.08
	Ge 2 +	3	34.22	Tb 1 +	1	5.85	28.37
	Ge 2 +	3	34.22	Dy 1 +	1	5.93	28.29
15	Ge 2 +	3	34.22	Ho 1 +	1	6.02	28.20
	Ge 2 +	3	34.22	Er 1 +	1	6.10	28.12
	Ge 2 +	3	34.22	Tm 1 +	1	6.18	28.04
	Ge 2 +	3	34.22	Yb 1 +	1	6.25	27.97
	Ge 2 +	3	34.22	Hf 1 +	1	6.60	27.62
20	Ge 2 +	3	34.22	Tl 1 +	1	6.11	28.11
	Ge 2 +	3	34.22	Th 1 +	1	6.10	28.12
	Ge 2 +	3	34.22	Pa 1 +	1	5.90	28.32
	Ge 2 +	3	34.22	U 1 +	1	6.05	28.17
	Ge 2 +	3	34.22	Np 1 +	1	6.20	28.02
25	Ge 2 +	3	34.22	Pu 1 +	1	6.06	28.16
	Ge 2 +	3	34.22	Am 1 +	1	5.99	28.23
	Ge 2 +	3	34.22	Cm 1 +	1	6.02	28.20
	Ge 2 +	3	34.22	Bk 1 +	1	6.23	27.99
	Ge 2 +	3	34.22	Cf 1 +	1	6.30	27.92
3)	Ge 2 +	3	34.22	Es 1 +	1	6.42	27.80
	Ge 3 +	4	45.71	As 2 +	2	18.63	27.08
	Ge 3 +	4	45.71	Rh 2 +	2	18.08	27.63
	Ge 3 +	4	45.71	Te 2 +	2	18.60	27.11
	Ge 3 +	4	45.71	Pt 2 +	2	18.56	27.15
35	Kr 2 +	3	36.95	As 1 +	1	9.81	27.14
	Nb 3 +	4	38.30	As 1 +	1	9.81	28.49

	Cd 2 +	3	37.48	As 1 +	1	9.81	27.67
	Te 3 +	4	37.41	As 1 +	1	9.81	27.60
	Mo 3 +	4	46.40	As 2 +	2	18.63	27.77
	Sb 4 +	5	56.00	As 3 +	3	28.35	27.65
5	Bi 4 +	5	56.00	As 3 +	3	28.35	27.65
	As 3 +	4	50.13	Br 2 +	2	21.80	28.33
	Kr 5 +	6	78.50	As 4 +	4	50.13	28.37
	As 3 +	4	50.13	Zr 3 +	3	22.99	27.14
	As 3 +	4	50.13	Nd 3 +	3	22.10	28.03
10	As 3 +	4	50.13	Pm 3 +	3	22.30	27.83
	As 3 +	4	50.13	Tb 3 +	3	21.91	28.22
	As 3 +	4	50.13	Dy 3 +	3	22.80	27.33
	As 3 +	4	50.13	Ho 3 +	3	22.84	27.29
	As 3 +	4	50.13	Er 3 +	3	22.74	27.39
15	As 4 +	5	63.63	Br 3 +	3	36.00	27.63
	Sr 5 +	6	90.80	As 5 +	5	63.63	27.17
	Se 6 +	7	155.40	As 6 +	6	127.60	27.80
	As 5 +	6	127.60	Rb 7 +	7	99.20	28.40
	Kr 2 +	3	36.95	Se 1 +	1	9.75	27.20
20	Cd 2 +	3	37.48	Se 1 +	1	9.75	27.73
	Te 3 +	4	37.41	Se 1 +	1	9.75	27.66
	Ce 3 +	4	36.76	Se 1 +	1	9.75	27.01
	Te 4 +	5	58.75	Se 3 +	3	30.82	27.93
	Rb 4 +	5	71.00	Se 4 +	4	42.94	28.06
25	Se 3 +	4	42.94	Tc 2 +	2	15.26	27.68
	Se 3 +	4	42.94	Sn 2 +	2	14.63	28.31
	Te 5 +	6	70.70	Se 4 +	4	42.94	27.76
	Se 3 +	4	42.94	Hf 2 +	2	14.90	28.04
	Se 3 +	4	42.94	Pb 2 +	2	15.03	27.91
30	Se 4 +	5	68.30	Rb 3 +	3	40.00	28.30
	Se 4 +	5	68.30	Sn 4 +	4	40.73	27.57
	Se 4 +	5	68.30	Nd 4 +	4	40.41	27.89
	Se 4 +	5	68.30	Pm 4 +	4	41.10	27.20
	Se 5 +	6	81.70	In 4 +	4	54.00	27.70
35	Rb 2 +	3	40.00	Br 1 +	1	11.81	28.19
	Pr 3 +	4	38.98	Br 1 +	1	11.81	27.17

Tb 3 +	4	39.80	Br 1 +	1	11.81	27.99
La 3 +	4	49.95	Br 2 +	2	21.80	28.15
Br 2 +	3	36.00	Pd 1 +	1	8.34	27.66
Br 2 +	3	36.00	Ag 1 +	1	7.58	28.42
Br 2 +	3	36.00	Cd 1 +	1	8.99	27.01
Br 2 +	3	36.00	Sb 1 +	1	8.64	27.36
Br 2 +	3	36.00	Ta 1 +	1	7.89	28.11
Br 2 +	3	36.00	W 1 +	1	7.98	28.02
Br 2 +	3	36.00	Re 1 +	1	7.88	28.12
Br 2 +	3	36.00	Os 1 +	1	8.70	27.30
Br 2 +	3	36.00	Po 1 +	1	8.42	27.58
Br 3 +	4	47.30	Pd 2 +	2	19.43	27.87
Br 3 +	4	47.30	In 2 +	2	18.87	28.43
Br 3 +	4	47.30	I 2 +	2	19.13	28.17
Br 3 +	4	47.30	La 3 +	3	19.18	28.12
Br 3 +	4	47.30	Ce 3 +	3	20.20	27.10
Br 4 +	5	59.70	Xe 3 +	3	32.10	27.60
Br 4 +	5	59.70	Pb 3 +	3	31.94	27.76
Y 6 +	7	116.00	Br 6 +	6	88.60	27.40
Br 5 +	6	88.60	Mo 5 +	5	61.20	27.40
Pm 3 +	4	41.10	Kr 1 +	1	14.00	27.10
Sm 3 +	4	41.40	Kr 1 +	1	14.00	27.40
Dy 3 +	4	41.50	Kr 1 +	1	14.00	27.50
Pb 3 +	4	42.32	Kr 1 +	1	14.00	28.32
Kr 3 +	4	52.50	Kr 2 +	2	24.36	28.14
Rb 3 +	4	52.60	Kr 2 +	2	24.36	28.24
Kr 4 +	5	64.70	Kr 3 +	3	36.95	27.75
Kr 2 +	3	36.95	Cd 1 +	1	8.99	27.96
Kr 2 +	3	36.95	Sb 1 +	1	8.64	28.31
Kr 2 +	3	36.95	Te 1 +	1	9.01	27.94
Kr 2 +	3	36.95	Os 1 +	1	8.70	28.25
Kr 2 +	3	36.95	Ir 1 +	1	9.10	27.85
Kr 2 +	3	36.95	Pt 1 +	1	9.00	27.95
Kr 2 +	3	36.95	Au 1 +	1	9.23	27.73
Kr 3 +	4	52.50	Kr 2 +	2	24.36	28.14
Kr 3 +	4	52.50	Nb 3 +	3	25.04	27.46

	Kr 3 +	4	52.50	Sb 3 +	3	25.30	27.20
	Kr 3 +	4	52.50	Cs 2 +	2	25.10	27.40
	Kr 3 +	4	52.50	Eu 3 +	3	24.90	27.60
	Kr 3 +	4	52.50	Yb 3 +	3	25.03	27.47
5	Kr 4 +	5	64.70	Kr 3 +	3	36.95	27.75
	Y 5 +	6	93.00	Kr 5 +	5	64.70	28.30
	Kr 4 +	5	64.70	Cd 3 +	3	37.48	27.22
	Kr 4 +	5	64.70	Te 4 +	4	37.41	27.29
	Kr 4 +	5	64.70	Ce 4 +	4	36.76	27.94
10	Sr 6 +	7	106.00	Kr 6 +	6	78.50	27.50
	Kr 5 +	6	78.50	Nb 5 +	5	50.55	27.95
	Xe 2 +	3	32.10	Rb 1 +	1	4.18	27.92
	Pb 2 +	3	31.94	Rb 1 +	1	4.18	27.76
	Rb 2 +	3	40.00	Y 2 +	2	12.24	27.76
15	Mo 5 +	6	68.00	Rb 3 +	3	40.00	28.00
	Rb 2 +	3	40.00	Xe 1 +	1	12.13	27.87
	Rb 2 +	3	40.00	Gd 2 +	2	12.09	27.91
	Rb 2 +	3	40.00	Tb 2 +	2	11.52	28.48
	Rb 2 +	3	40.00	Dy 2 +	2	11.67	28.33
20	Rb 2 +	3	40.00	Ho 2 +	2	11.80	28.20
	Rb 2 +	3	40.00	Er 2 +	2	11.93	28.07
	Rb 2 +	3	40.00	Tm 2 +	2	12.05	27.95
	Rb 2 +	3	40.00	Yb 2 +	2	12.18	27.82
	Rb 3 +	4	52.60	Nb 3 +	3	25.04	27.56
25	Rb 3 +	4	52.60	Sb 3 +	3	25.30	27.30
	Rb 3 +	4	52.60	Cs 2 +	2	25.10	27.50
	Rb 3 +	4	52.60	Eu 3 +	3	24.90	27.70
	Rb 3 +	4	52.60	Yb 3 +	3	25.03	27.57
	Rb 3 +	4	52.60	Bi 3 +	3	25.56	27.04
30	Rb 6 +	7	99.20	Rb 5 +	5	71.00	28.20
	Rb 4 +	5	71.00	Sr 3 +	3	43.60	27.40
	Rb 4 +	5	71.00	Eu 4 +	4	42.60	28.40
	Rb 4 +	5	71.00	Er 4 +	4	42.60	28.40
	Rb 4 +	5	71.00	Tm 4 +	4	42.70	28.30
35	Rb 4 +	5	71.00	Yb 4 +	4	43.70	27.30
	Rb 5 +	6	84.40	Sr 4 +	4	57.00	27.40

Rb 5 +	6	84.40		Sb 5 +	5	56.00	28.40
Rb 5 +	6	84.40		Bi 5 +	5	56.00	28.40
Rb 6 +	7	99.20		Rb 5 +	5	71.00	28.20
Rb 6 +	7	99.20		Sr 5 +	5	71.60	27.60
Mo 6 +	7	126.80		Rb 7 +	7	99.20	27.60
Rb 7 +	8	136.00		Sb 6 +	6	108.00	28.00
Pd 2 +	3	32.93		Sr 1 +	1	5.70	27.24
I 2 +	3	33.00		Sr 1 +	1	5.70	27.31
Hf 3 +	4	33.33		Sr 1 +	1	5.70	27.64
Nb 3 +	4	38.30		Sr 2 +	2	11.03	27.27
Pr 3 +	4	38.98		Sr 2 +	2	11.03	27.95
Sr 4 +	5	71.60		Sr 3 +	3	43.60	28.00
Sr 2 +	3	43.60		Mo 2 +	2	16.15	27.45
Sr 2 +	3	43.60		Tc 2 +	2	15.26	28.34
Sr 2 +	3	43.60		Sb 2 +	2	16.53	27.07
Te 5 +	6	70.70		Sr 3 +	3	43.60	27.10
Sr 3 +	4	57.00		Tc 3 +	3	29.54	27.46
Sr 3 +	4	57.00		Tl 3 +	3	29.83	27.17
Sr 4 +	5	71.60		Sr 3 +	3	43.60	28.00
Sr 4 +	5	71.60		Sb 4 +	4	44.20	27.40
Sr 4 +	5	71.60		Gd 4 +	4	44.00	27.60
Sr 4 +	5	71.60		Yb 4 +	4	43.70	27.90
Zr 3 +	4	34.34		Y 1 +	1	6.38	27.96
Ag 2 +	3	34.83		Y 1 +	1	6.38	28.45
Hg 2 +	3	34.20		Y 1 +	1	6.38	27.82
Sn 3 +	4	40.73		Y 2 +	2	12.24	28.49
Nd 3 +	4	40.41		Y 2 +	2	12.24	28.17
Tb 3 +	4	39.80		Y 2 +	2	12.24	27.56
Y 3 +	4	61.80		Zr 4 +	4	34.34	27.46
Y 3 +	4	61.80		Hf 4 +	4	33.33	28.47
Y 3 +	4	61.80		Hg 3 +	3	34.20	27.60
Y 4 +	5	77.00		La 4 +	4	49.95	27.05
Y 6 +	7	116.00		Bi 6 +	6	88.30	27.70
Zr 3 +	4	34.34		Zr 1 +	1	6.84	27.50
Ag 2 +	3	34.83		Zr 1 +	1	6.84	27.99
Hg 2 +	3	34.20		Zr 1 +	1	6.84	27.36

	Sn 3 +	4	40.73	Zr 2 +	2	13.13	27.60
	Nd 3 +	4	40.41	Zr 2 +	2	13.13	27.28
	Pm 3 +	4	41.10	Zr 2 +	2	13.13	27.97
	Sm 3 +	4	41.40	Zr 2 +	2	13.13	28.27
5	Dy 3 +	4	41.50	Zr 2 +	2	13.13	28.37
	Nb 4 +	5	50.55	Zr 3 +	3	22.99	27.56
	Zr 3 +	4	34.34	Zr 1 +	1	6.84	27.50
	Zr 3 +	4	34.34	Nb 1 +	1	6.88	27.46
	Zr 3 +	4	34.34	Mo 1 +	1	7.10	27.24
10	Zr 3 +	4	34.34	Tc 1 +	1	7.28	27.06
	Zr 3 +	4	34.34	Gd 1 +	1	6.14	28.20
	Zr 3 +	4	34.34	Tb 1 +	1	5.85	28.49
	Zr 3 +	4	34.34	Dy 1 +	1	5.93	28.41
	Zr 3 +	4	34.34	Ho 1 +	1	6.02	28.32
15	Zr 3 +	4	34.34	Er 1 +	1	6.10	28.24
	Zr 3 +	4	34.34	Tm 1 +	1	6.18	28.16
	Zr 3 +	4	34.34	Yb 1 +	1	6.25	28.09
	Zr 3 +	4	34.34	Hf 1 +	1	6.60	27.74
	Zr 3 +	4	34.34	Tl 1 +	1	6.11	28.23
20	Zr 3 +	4	34.34	Bi 1 +	1	7.29	27.05
	Zr 3 +	4	34.34	Th 1 +	1	6.10	28.24
	Zr 3 +	4	34.34	Pa 1 +	1	5.90	28.44
	Zr 3 +	4	34.34	U 1 +	1	6.05	28.29
	Zr 3 +	4	34.34	Np 1 +	1	6.20	28.14
25	Zr 3 +	4	34.34	Pu 1 +	1	6.06	28.28
	Zr 3 +	4	34.34	Am 1 +	1	5.99	28.35
	Zr 3 +	4	34.34	Cm 1 +	1	6.02	28.32
	Zr 3 +	4	34.34	Bk 1 +	1	6.23	28.11
	Zr 3 +	4	34.34	Cf 1 +	1	6.30	28.04
30	Zr 3 +	4	34.34	Es 1 +	1	6.42	27.92
	Zr 4 +	5	81.50	In 4 +	4	54.00	27.50
	Ag 2 +	3	34.83	Nb 1 +	1	6.88	27.95
	Hg 2 +	3	34.20	Nb 1 +	1	6.88	27.32
	Sm 3 +	4	41.40	Nb 2 +	2	14.32	27.08
35	Eu 3 +	4	42.60	Nb 2 +	2	14.32	28.28
	Dy 3 +	4	41.50	Nb 2 +	2	14.32	27.18

Ho 3 +	4	42.50	Nb 2 +	2	14.32	28.18
Er 3 +	4	42.60	Nb 2 +	2	14.32	28.28
Tm 3 +	4	42.70	Nb 2 +	2	14.32	28.38
Pb 3 +	4	42.32	Nb 2 +	2	14.32	28.00
Nb 3 +	4	38.30	I 1 +	1	10.45	27.85
Nb 3 +	4	38.30	Ba 2 +	2	10.00	28.30
Nb 3 +	4	38.30	La 2 +	2	11.06	27.24
Nb 3 +	4	38.30	Ce 2 +	2	10.85	27.45
Nb 3 +	4	38.30	Pr 2 +	2	10.55	27.75
Nb 3 +	4	38.30	Nd 2 +	2	10.73	27.57
Nb 3 +	4	38.30	Pm 2 +	2	10.90	27.40
Nb 3 +	4	38.30	Sm 2 +	2	11.07	27.23
Nb 3 +	4	38.30	Eu 2 +	2	11.24	27.06
Nb 3 +	4	38.30	Hg 1 +	1	10.44	27.86
Nb 3 +	4	38.30	Rn 1 +	1	10.75	27.55
Nb 3 +	4	38.30	Ra 2 +	2	10.15	28.15
Nb 4 +	5	50.55	Nd 3 +	3	22.10	28.45
Nb 4 +	5	50.55	Pm 3 +	3	22.30	28.25
Nb 4 +	5	50.55	Sm 3 +	3	23.40	27.15
Nb 4 +	5	50.55	Dy 3 +	3	22.80	27.75
Nb 4 +	5	50.55	Ho 3 +	3	22.84	27.71
Nb 4 +	5	50.55	Er 3 +	3	22.74	27.81
Nb 4 +	5	50.55	Hf 3 +	3	23.30	27.25
Mo 7 +	8	153.00	Nb 7 +	7	125.00	28.00
Ag 2 +	3	34.83	Mo 1 +	1	7.10	27.73
Hg 2 +	3	34.20	Mo 1 +	1	7.10	27.10
Sb 3 +	4	44.20	Mo 2 +	2	16.15	28.05
Gd 3 +	4	44.00	Mo 2 +	2	16.15	27.85
Yb 3 +	4	43.70	Mo 2 +	2	16.15	27.55
Mo 3 +	4	46.40	Rh 2 +	2	18.08	28.32
Mo 3 +	4	46.40	In 2 +	2	18.87	27.53
Mo 3 +	4	46.40	Te 2 +	2	18.60	27.80
Mo 3 +	4	46.40	I 2 +	2	19.13	27.27
Mo 3 +	4	46.40	La 3 +	3	19.18	27.22
Mo 3 +	4	46.40	Pt 2 +	2	18.56	27.84
Mo 3 +	4	46.40	Hg 2 +	2	18.76	27.64

	Mo 4 +	5	61.20	Pd 3 +	3	32.93	28.27
	Mo 4 +	5	61.20	I 3 +	3	33.00	28.20
	Mo 4 +	5	61.20	Hf 4 +	4	33.33	27.87
	Bi 5 +	6	88.30	Mo 5 +	5	61.20	27.10
5	Mo 5 +	6	68.00	Sn 4 +	4	40.73	27.27
	Mo 5 +	6	68.00	Nd 4 +	4	40.41	27.59
	Mo 5 +	6	68.00	Tb 4 +	4	39.80	28.20
	Ag 2 +	3	34.83	Tc 1 +	1	7.28	27.55
	Eu 3 +	4	42.60	Tc 2 +	2	15.26	27.34
10	Ho 3 +	4	42.50	Tc 2 +	2	15.26	27.24
	Er 3 +	4	42.60	Tc 2 +	2	15.26	27.34
	Tm 3 +	4	42.70	Tc 2 +	2	15.26	27.44
	Yb 3 +	4	43.70	Tc 2 +	2	15.26	28.44
	Pb 3 +	4	42.32	Tc 2 +	2	15.26	27.06
15	Ag 2 +	3	34.83	Ru 1 +	1	7.37	27.46
	Sb 3 +	4	44.20	Ru 2 +	2	16.76	27.44
	Gd 3 +	4	44.00	Ru 2 +	2	16.76	27.24
	Lu 3 +	4	45.19	Ru 2 +	2	16.76	28.43
	Sb 4 +	5	56.00	Ru 3 +	3	28.47	27.53
20	Bi 4 +	5	56.00	Ru 3 +	3	28.47	27.53
	Ag 2 +	3	34.83	Rh 1 +	1	7.46	27.37
	Lu 3 +	4	45.19	Rh 2 +	2	18.08	27.11
	Bi 3 +	4	45.30	Rh 2 +	2	18.08	27.22
	Te 4 +	5	58.75	Rh 3 +	3	31.06	27.69
25	Rh 2 +	3	31.06	Cs 1 +	1	3.89	27.17
	Ce 3 +	4	36.76	Pd 1 +	1	8.34	28.42
	Pd 2 +	3	32.93	In 1 +	1	5.79	27.14
	Pd 2 +	3	32.93	Ba 1 +	1	5.21	27.72
	Pd 2 +	3	32.93	La 1 +	1	5.58	27.35
30	Pd 2 +	3	32.93	Ce 1 +	1	5.47	27.46
	Pd 2 +	3	32.93	Pr 1 +	1	5.42	27.51
	Pd 2 +	3	32.93	Nd 1 +	1	5.49	27.44
	Pd 2 +	3	32.93	Pm 1 +	1	5.55	27.38
	Pd 2 +	3	32.93	Sm 1 +	1	5.63	27.30
35	Pd 2 +	3	32.93	Eu 1 +	1	5.67	27.26
	Pd 2 +	3	32.93	Tb 1 +	1	5.85	27.08

Pd 2 +	3	32.93	Dy 1 +	1	5.93	27.00
Pd 2 +	3	32.93	Lu 1 +	1	5.43	27.50
Pd 2 +	3	32.93	Ra 1 +	1	5.28	27.65
Pd 2 +	3	32.93	Ac 1 +	1	5.20	27.73
Pd 2 +	3	32.93	Pa 1 +	1	5.90	27.03
Ag 2 +	3	34.83	Ag 1 +	1	7.58	27.25
La 3 +	4	49.95	Ag 2 +	2	21.49	28.46
Ag 2 +	3	34.83	Ag 1 +	1	7.58	27.25
Ag 2 +	3	34.83	Sn 1 +	1	7.34	27.49
Ag 2 +	3	34.83	Hf 1 +	1	6.60	28.23
Ag 2 +	3	34.83	Pb 1 +	1	7.42	27.41
Ag 2 +	3	34.83	Bi 1 +	1	7.29	27.54
Ag 2 +	3	34.83	Es 1 +	1	6.42	28.41
Cd 2 +	3	37.48	Cd 1 +	1	8.99	28.49
Te 3 +	4	37.41	Cd 1 +	1	8.99	28.42
Ce 3 +	4	36.76	Cd 1 +	1	8.99	27.76
Sb 3 +	4	44.20	Cd 2 +	2	16.91	27.29
Gd 3 +	4	44.00	Cd 2 +	2	16.91	27.09
Lu 3 +	4	45.19	Cd 2 +	2	16.91	28.28
Bi 3 +	4	45.30	Cd 2 +	2	16.91	28.39
Cd 2 +	3	37.48	Cd 1 +	1	8.99	28.49
Cd 2 +	3	37.48	Te 1 +	1	9.01	28.47
Cd 2 +	3	37.48	I 1 +	1	10.45	27.03
Cd 2 +	3	37.48	Ba 2 +	2	10.00	27.48
Cd 2 +	3	37.48	Ir 1 +	1	9.10	28.38
Cd 2 +	3	37.48	Pt 1 +	1	9.00	28.48
Cd 2 +	3	37.48	Au 1 +	1	9.23	28.25
Cd 2 +	3	37.48	Hg 1 +	1	10.44	27.04
Cd 2 +	3	37.48	Ra 2 +	2	10.15	27.33
I 2 +	3	33.00	In 1 +	1	5.79	27.21
Hf 3 +	4	33.33	In 1 +	1	5.79	27.54
Hg 2 +	3	34.20	In 1 +	1	5.79	28.41
Sb 4 +	5	56.00	In 3 +	3	28.03	27.97
Bi 4 +	5	56.00	In 3 +	3	28.03	27.97
In 3 +	4	54.00	Bi 3 +	3	25.56	28.44
Eu 3 +	4	42.60	Sn 2 +	2	14.63	27.97

	Ho 3 +	4	42.50	Sn 2 +	2	14.63	27.87
	Er 3 +	4	42.60	Sn 2 +	2	14.63	27.97
	Tm 3 +	4	42.70	Sn 2 +	2	14.63	28.07
	Pb 3 +	4	42.32	Sn 2 +	2	14.63	27.69
5	Te 4 +	5	58.75	Sn 3 +	3	30.50	28.25
	Pb 4 +	5	68.80	Sn 4 +	4	40.73	28.07
	Sn 4 +	5	72.28	Sb 4 +	4	44.20	28.08
	Sn 4 +	5	72.28	Gd 4 +	4	44.00	28.28
	Sn 4 +	5	72.28	Lu 4 +	4	45.19	27.09
10	Ce 3 +	4	36.76	Sb 1 +	1	8.64	28.12
	Sb 3 +	4	44.20	Sb 2 +	2	16.53	27.67
	Gd 3 +	4	44.00	Sb 2 +	2	16.53	27.47
	Yb 3 +	4	43.70	Sb 2 +	2	16.53	27.17
	Sb 3 +	4	44.20	Sb 2 +	2	16.53	27.67
15	Sb 3 +	4	44.20	Bi 2 +	2	16.69	27.51
	Sb 4 +	5	56.00	Te 3 +	3	27.96	28.04
	Te 3 +	4	37.41	Te 1 +	1	9.01	28.40
	Ce 3 +	4	36.76	Te 1 +	1	9.01	27.75
	Bi 4 +	5	56.00	Te 3 +	3	27.96	28.04
20	Te 3 +	4	37.41	Te 1 +	1	9.01	28.40
	Te 3 +	4	37.41	Ba 2 +	2	10.00	27.41
	Te 3 +	4	37.41	Ir 1 +	1	9.10	28.31
	Te 3 +	4	37.41	Pt 1 +	1	9.00	28.41
	Te 3 +	4	37.41	Au 1 +	1	9.23	28.18
25	Te 3 +	4	37.41	Ra 2 +	2	10.15	27.26
	Te 5 +	6	70.70	Eu 4 +	4	42.60	28.10
	Te 5 +	6	70.70	Ho 4 +	4	42.50	28.20
	Te 5 +	6	70.70	Er 4 +	4	42.60	28.10
	Te 5 +	6	70.70	Tm 4 +	4	42.70	28.00
30	Te 5 +	6	70.70	Pb 4 +	4	42.32	28.38
	I 2 +	3	33.00	Ba 1 +	1	5.21	27.79
	I 2 +	3	33.00	La 1 +	1	5.58	27.42
	I 2 +	3	33.00	Ce 1 +	1	5.47	27.53
	I 2 +	3	33.00	Pr 1 +	1	5.42	27.58
35	I 2 +	3	33.00	Nd 1 +	1	5.49	27.51
	I 2 +	3	33.00	Pm 1 +	1	5.55	27.45

I 2 +	3	33.00	Sm 1 +	1	5.63	27.37
I 2 +	3	33.00	Eu 1 +	1	5.67	27.33
I 2 +	3	33.00	Tb 1 +	1	5.85	27.15
I 2 +	3	33.00	Dy 1 +	1	5.93	27.07
I 2 +	3	33.00	Lu 1 +	1	5.43	27.57
I 2 +	3	33.00	Ra 1 +	1	5.28	27.72
I 2 +	3	33.00	Ac 1 +	1	5.20	27.80
I 2 +	3	33.00	Pa 1 +	1	5.90	27.10
I 2 +	3	33.00	Am 1 +	1	5.99	27.01
Nd 3 +	4	40.41	Xe 1 +	1	12.13	28.28
Tb 3 +	4	39.80	Xe 1 +	1	12.13	27.67
Xe 2 +	3	32.10	Cs 1 +	1	3.89	28.21
Pb 2 +	3	31.94	Cs 1 +	1	3.89	28.04
Hf 3 +	4	33.33	Ba 1 +	1	5.21	28.12
Hf 3 +	4	33.33	La 1 +	1	5.58	27.75
Pr 3 +	4	38.98	La 2 +	2	11.06	27.92
La 3 +	4	49.95	Pr 3 +	3	21.62	28.33
La 3 +	4	49.95	Nd 3 +	3	22.10	27.85
La 3 +	4	49.95	Pm 3 +	3	22.30	27.65
La 3 +	4	49.95	Tb 3 +	3	21.91	28.04
La 3 +	4	49.95	Dy 3 +	3	22.80	27.15
La 3 +	4	49.95	Ho 3 +	3	22.84	27.11
La 3 +	4	49.95	Er 3 +	3	22.74	27.21
Hf 3 +	4	33.33	Ce 1 +	1	5.47	27.86
Pr 3 +	4	38.98	Ce 2 +	2	10.85	28.13
Ce 3 +	4	36.76	Os 1 +	1	8.70	28.06
Ce 3 +	4	36.76	Ir 1 +	1	9.10	27.66
Ce 3 +	4	36.76	Pt 1 +	1	9.00	27.76
Ce 3 +	4	36.76	Au 1 +	1	9.23	27.53
Ce 3 +	4	36.76	Po 1 +	1	8.42	28.34
Hf 3 +	4	33.33	Pr 1 +	1	5.42	27.91
Pr 3 +	4	38.98	Pr 2 +	2	10.55	28.43
Pr 3 +	4	38.98	Pr 2 +	2	10.55	28.43
Pr 3 +	4	38.98	Nd 2 +	2	10.73	28.25
Pr 3 +	4	38.98	Pm 2 +	2	10.90	28.08
Pr 3 +	4	38.98	Sm 2 +	2	11.07	27.91

Pr 3 +	4	38.98	Eu 2 +	2	11.24	27.74
Pr 3 +	4	38.98	Tb 2 +	2	11.52	27.46
Pr 3 +	4	38.98	Dy 2 +	2	11.67	27.31
Pr 3 +	4	38.98	Ho 2 +	2	11.80	27.18
Pr 3 +	4	38.98	Er 2 +	2	11.93	27.05
Pr 3 +	4	38.98	Rn 1 +	1	10.75	28.23
Hf 3 +	4	33.33	Nd 1 +	1	5.49	27.84
Nd 3 +	4	40.41	Gd 2 +	2	12.09	28.32
Nd 3 +	4	40.41	Er 2 +	2	11.93	28.48
Nd 3 +	4	40.41	Tm 2 +	2	12.05	28.36
Nd 3 +	4	40.41	Yb 2 +	2	12.18	28.23
Pb 4 +	5	68.80	Nd 4 +	4	40.41	28.39
Hf 3 +	4	33.33	Pm 1 +	1	5.55	27.78
Pm 3 +	4	41.10	Lu 2 +	2	13.90	27.20
Pb 4 +	5	68.80	Pm 4 +	4	41.10	27.70
Hf 3 +	4	33.33	Sm 1 +	1	5.63	27.70
Sm 3 +	4	41.40	Lu 2 +	2	13.90	27.50
Pb 4 +	5	68.80	Sm 4 +	4	41.40	27.40
Hf 3 +	4	33.33	Eu 1 +	1	5.67	27.66
Eu 3 +	4	42.60	Hf 2 +	2	14.90	27.70
Eu 3 +	4	42.60	Pb 2 +	2	15.03	27.57
Hf 3 +	4	33.33	Gd 1 +	1	6.14	27.19
Hg 2 +	3	34.20	Gd 1 +	1	6.14	28.06
Tb 3 +	4	39.80	Gd 2 +	2	12.09	27.71
Gd 3 +	4	44.00	Bi 2 +	2	16.69	27.31
Hf 3 +	4	33.33	Tb 1 +	1	5.85	27.48
Hg 2 +	3	34.20	Tb 1 +	1	5.85	28.35
Tb 3 +	4	39.80	Tb 2 +	2	11.52	28.28
Tb 3 +	4	39.80	Tb 2 +	2	11.52	28.28
Tb 3 +	4	39.80	Dy 2 +	2	11.67	28.13
Tb 3 +	4	39.80	Ho 2 +	2	11.80	28.00
Tb 3 +	4	39.80	Er 2 +	2	11.93	27.87
Tb 3 +	4	39.80	Tm 2 +	2	12.05	27.75
Tb 3 +	4	39.80	Yb 2 +	2	12.18	27.62
Hf 3 +	4	33.33	Dy 1 +	1	5.93	27.40
Hg 2 +	3	34.20	Dy 1 +	1	5.93	28.27

Dy 3 +	4	41.50		Lu 2 +	2	13.90	27.60
Pb 4 +	5	68.80		Dy 4 +	4	41.50	27.30
Hf 3 +	4	33.33		Ho 1 +	1	6.02	27.31
Hg 2 +	3	34.20		Ho 1 +	1	6.02	28.18
Ho 3 +	4	42.50		Hf 2 +	2	14.90	27.60
Ho 3 +	4	42.50		Pb 2 +	2	15.03	27.47
Hf 3 +	4	33.33		Er 1 +	1	6.10	27.23
Hg 2 +	3	34.20		Er 1 +	1	6.10	28.10
Er 3 +	4	42.60		Hf 2 +	2	14.90	27.70
Er 3 +	4	42.60		Pb 2 +	2	15.03	27.57
Hf 3 +	4	33.33		Tm 1 +	1	6.18	27.15
Hg 2 +	3	34.20		Tm 1 +	1	6.18	28.02
Tm 3 +	4	42.70		Hf 2 +	2	14.90	27.80
Tm 3 +	4	42.70		Pb 2 +	2	15.03	27.67
Hf 3 +	4	33.33		Yb 1 +	1	6.25	27.08
Hg 2 +	3	34.20		Yb 1 +	1	6.25	27.95
Yb 3 +	4	43.70		Bi 2 +	2	16.69	27.01
Hf 3 +	4	33.33		Lu 1 +	1	5.43	27.90
Pb 3 +	4	42.32		Lu 2 +	2	13.90	28.42
Lu 3 +	4	45.19		Bi 2 +	2	16.69	28.50
Hg 2 +	3	34.20		Hf 1 +	1	6.60	27.60
Pb 3 +	4	42.32		Hf 2 +	2	14.90	27.42
Hf 3 +	4	33.33		Tl 1 +	1	6.11	27.22
Hf 3 +	4	33.33		Ra 1 +	1	5.28	28.05
Hf 3 +	4	33.33		Ac 1 +	1	5.20	28.13
Hf 3 +	4	33.33		Th 1 +	1	6.10	27.23
Hf 3 +	4	33.33		Pa 1 +	1	5.90	27.43
Hf 3 +	4	33.33		U 1 +	1	6.05	27.28
Hf 3 +	4	33.33		Np 1 +	1	6.20	27.13
Hf 3 +	4	33.33		Pu 1 +	1	6.06	27.27
Hf 3 +	4	33.33		Am 1 +	1	5.99	27.34
Hf 3 +	4	33.33		Cm 1 +	1	6.02	27.31
Hf 3 +	4	33.33		Bk 1 +	1	6.23	27.10
Hg 2 +	3	34.20		Cf 1 +	1	6.30	27.03
Hg 2 +	3	34.20		Tl 1 +	1	6.11	28.09
				Th 1 +	1	6.10	28.10

	Hg 2 +	3	34.20	Pa 1 +	1	5.90	28.30
	Hg 2 +	3	34.20	U 1 +	1	6.05	28.15
	Hg 2 +	3	34.20	Np 1 +	1	6.20	28.00
	Hg 2 +	3	34.20	Pu 1 +	1	6.06	28.14
	Hg 2 +	3	34.20	Am 1 +	1	5.99	28.21
	Hg 2 +	3	34.20	Cm 1 +	1	6.02	28.18
	Hg 2 +	3	34.20	Bk 1 +	1	6.23	27.97
	Hg 2 +	3	34.20	Cf 1 +	1	6.30	27.90
	Hg 2 +	3	34.20	Es 1 +	1	6.42	27.78
	Pb 3 +	4	42.32	Pb 2 +	2	15.03	27.29
	Pb 3 +	4	42.32	Pb 2 +	2	15.03	27.29

n = 16 (resonance shrinkage energy is given by $\frac{n}{2}$ 27.21 eV; with n = 16, the resonance shrinkage energy is 217.68)

Atom Oxidized	n	nth Ionization Energy (eV)	Atom Reduced	n	nth Ionization Energy (eV)	Energy Hole (eV)
Ne 7 +	8	239.09	He 1 +	1	24.59	214.50
Al 6 +	7	241.43	He 1 +	1	24.59	216.84
Mg 6 +	7	224.94	Li 1 +	1	5.39	219.55
P 5 +	6	220.43	Li 1 +	1	5.39	215.04
B 4 +	5	340.22	Li 3 +	3	122.45	217.77
Mg 6 +	7	224.94	Be 1 +	1	9.32	215.62
Ne 7 +	8	239.09	Be 2 +	2	18.21	220.88
Mg 6 +	7	224.94	B 1 +	1	8.30	216.64
Al 6 +	7	241.43	B 2 +	2	25.15	216.28
B 3 +	4	259.37	Ne 2 +	2	40.96	218.41
B 3 +	4	259.37	Si 4 +	4	45.14	214.23
B 3 +	4	259.37	Cl 3 +	3	39.61	219.76
B 3 +	4	259.37	Ar 3 +	3	40.74	218.63
B 3 +	4	259.37	Ti 4 +	4	43.27	216.10
B 3 +	4	259.37	Zn 3 +	3	39.72	219.65
B 3 +	4	259.37	Se 4 +	4	42.94	216.42
B 3 +	4	259.37	Rb 3 +	3	40.00	219.37
B 3 +	4	259.37	Sr 3 +	3	43.60	215.77

B 3 +	4	259.37	
B 3 +	4	259.37	
B 3 +	4	259.37	
B 3 +	4	259.37	
B 3 +	4	259.37	
B 3 +	4	259.37	
B 3 +	4	259.37	
B 3 +	4	259.37	
B 3 +	4	259.37	
B 3 +	4	259.37	
B 3 +	4	259.37	
B 3 +	4	259.37	
B 3 +	4	259.37	
B 3 +	4	259.37	
B 3 +	4	259.37	
B 4 +	5	340.22	
B 4 +	5	340.22	
B 4 +	5	340.22	
B 4 +	5	340.22	
B 4 +	5	340.22	
B 4 +	5	340.22	
B 4 +	5	340.22	
B 4 +	5	340.22	
B 4 +	5	340.22	
Ne 7 +	8	239.09	
Al 6 +	7	241.43	
Na 7 +	8	264.18	
Mg 7 +	8	265.90	
P 6 +	7	263.22	
Al 7 +	8	284.59	
S 6 +	7	280.93	
C 4 +	5	392.08	
C 4 +	5	392.08	
C 4 +	5	392.08	
Sn 4 +	4	40.73	218.63
Sb 4 +	4	44.20	215.17
Pr 4 +	4	38.98	220.39
Nd 4 +	4	40.41	218.96
Pm 4 +	4	41.10	218.27
Sm 4 +	4	41.40	217.97
Eu 4 +	4	42.60	216.77
Gd 4 +	4	44.00	215.37
Tb 4 +	4	39.80	219.57
Dy 4 +	4	41.50	217.87
Ho 4 +	4	42.50	216.87
Er 4 +	4	42.60	216.77
Tm 4 +	4	42.70	216.67
Yb 4 +	4	43.70	215.67
Lu 4 +	4	45.19	214.18
Pb 4 +	4	42.32	217.05
Bi 4 +	4	45.30	214.07
Ne 5 +	5	126.21	214.01
Al 4 +	4	119.99	220.23
Ar 7 +	7	124.32	215.90
Ti 6 +	6	119.36	220.86
Mn 7 +	7	119.27	220.95
Fe 7 +	7	125.00	215.22
Kr 8 +	8	126.00	214.22
Sr 8 +	8	122.30	217.92
Nb 7 +	7	125.00	215.22
C 2 +	2	24.38	214.71
C 2 +	2	24.38	217.05
C 3 +	3	47.89	216.29
C 3 +	3	47.89	218.01
C 3 +	3	47.89	215.33
C 4 +	4	64.49	220.10
C 4 +	4	64.49	216.44
Na 6 +	6	172.15	219.93
V 8 +	8	173.70	218.38
Zn 8 +	8	174.00	218.08

	Hg 2 +	3	34.20	Pa 1 +	1	5.90	28.30
	Hg 2 +	3	34.20	U 1 +	1	6.05	28.15
	Hg 2 +	3	34.20	Np 1 +	1	6.20	28.00
	Hg 2 +	3	34.20	Pu 1 +	1	6.06	28.14
5	Hg 2 +	3	34.20	Am 1 +	1	5.99	28.21
	Hg 2 +	3	34.20	Cm 1 +	1	6.02	28.18
	Hg 2 +	3	34.20	Bk 1 +	1	6.23	27.97
	Hg 2 +	3	34.20	Cf 1 +	1	6.30	27.90
	Hg 2 +	3	34.20	Es 1 +	1	6.42	27.78
10	Pb 3 +	4	42.32	Pb 2 +	2	15.03	27.29
	Pb 3 +	4	42.32	Pb 2 +	2	15.03	27.29

n = 16 (resonance shrinkage energy is given by $\frac{n}{2}$ 27.21 eV; with n = 16, the resonance shrinkage energy is 217.68)

	Atom Oxidized	n	nth Ionization Energy (eV)	Atom Reduced	n	nth Ionization Energy (eV)	Energy Hole (eV)
	Ne 7 +	8	239.09	He 1 +	1	24.59	214.50
	Al 6 +	7	241.43	He 1 +	1	24.59	216.84
20	Mg 6 +	7	224.94	Li 1 +	1	5.39	219.55
	P 5 +	6	220.43	Li 1 +	1	5.39	215.04
	B 4 +	5	340.22	Li 3 +	3	122.45	217.77
	Mg 6 +	7	224.94	Be 1 +	1	9.32	215.62
	Ne 7 +	8	239.09	Be 2 +	2	18.21	220.88
25	Mg 6 +	7	224.94	B 1 +	1	8.30	216.64
	Al 6 +	7	241.43	B 2 +	2	25.15	216.28
	B 3 +	4	259.37	Ne 2 +	2	40.96	218.41
	B 3 +	4	259.37	Si 4 +	4	45.14	214.23
	B 3 +	4	259.37	Cl 3 +	3	39.61	219.76
30	B 3 +	4	259.37	Ar 3 +	3	40.74	218.63
	B 3 +	4	259.37	Ti 4 +	4	43.27	216.10
	B 3 +	4	259.37	Zn 3 +	3	39.72	219.65
	B 3 +	4	259.37	Se 4 +	4	42.94	216.42
	B 3 +	4	259.37	Rb 3 +	3	40.00	219.37
35	B 3 +	4	259.37	Sr 3 +	3	43.60	215.77

	Si 6 +	7	246.52	N 2 +	2	29.60	216.92
	Na 7 +	8	264.18	N 3 +	3	47.45	216.73
	Mg 7 +	8	265.90	N 3 +	3	47.45	218.45
	P 6 +	7	263.22	N 3 +	3	47.45	215.77
5	S 7 +	8	328.23	O 5 +	5	113.90	214.33
	F 7 +	8	953.89	O 7 +	7	739.32	214.57
	S 6 +	7	280.93	F 3 +	3	62.71	218.22
	Si 7 +	8	303.17	F 4 +	4	87.14	216.03
	Ne 7 +	8	239.09	Ne 1 +	1	21.56	217.53
10	Al 6 +	7	241.43	Ne 1 +	1	21.56	219.87
	S 6 +	7	280.93	Ne 3 +	3	63.45	217.48
	Ne 7 +	8	239.09	Ne 1 +	1	21.56	217.53
	Ne 7 +	8	239.09	Al 2 +	2	18.83	220.26
	Ne 7 +	8	239.09	P 2 +	2	19.73	219.36
15	Ne 7 +	8	239.09	S 2 +	2	23.33	215.76
	Ne 7 +	8	239.09	Cl 2 +	2	23.81	215.28
	Ne 7 +	8	239.09	Sc 3 +	3	24.76	214.33
	Ne 7 +	8	239.09	Ni 2 +	2	18.17	220.92
	Ne 7 +	8	239.09	Cu 2 +	2	20.29	218.80
20	Ne 7 +	8	239.09	Ga 2 +	2	20.51	218.58
	Ne 7 +	8	239.09	As 2 +	2	18.63	220.46
	Ne 7 +	8	239.09	Se 2 +	2	21.19	217.90
	Ne 7 +	8	239.09	Br 2 +	2	21.80	217.29
	Ne 7 +	8	239.09	Kr 2 +	2	24.36	214.73
25	Ne 7 +	8	239.09	Y 3 +	3	20.52	218.57
	Ne 7 +	8	239.09	Zr 3 +	3	22.99	216.10
	Ne 7 +	8	239.09	Nb 3 +	3	25.04	214.05
	Ne 7 +	8	239.09	Pd 2 +	2	19.43	219.66
	Ne 7 +	8	239.09	Ag 2 +	2	21.49	217.60
30	Ne 7 +	8	239.09	In 2 +	2	18.87	220.22
	Ne 7 +	8	239.09	Te 2 +	2	18.60	220.49
	Ne 7 +	8	239.09	I 2 +	2	19.13	219.96
	Ne 7 +	8	239.09	Xe 2 +	2	21.21	217.88
	Ne 7 +	8	239.09	La 3 +	3	19.18	219.91
35	Ne 7 +	8	239.09	Ce 3 +	3	20.20	218.89
	Ne 7 +	8	239.09	Pr 3 +	3	21.62	217.47

Ne 7 +	8	239.09	
Ne 7 +	8	239.09	
Ne 7 +	8	239.09	
Ne 7 +	8	239.09	
Ne 7 +	8	239.09	
Ne 7 +	8	239.09	
Ne 7 +	8	239.09	
Ne 7 +	8	239.09	
Ne 7 +	8	239.09	
Ne 7 +	8	239.09	
Ne 7 +	8	239.09	
Ne 7 +	8	239.09	
Ne 7 +	8	239.09	
Ne 7 +	8	239.09	
Ne 7 +	8	239.09	
Mg 6 +	7	224.94	
P 5 +	6	220.43	
Na 7 +	8	264.18	
Mg 7 +	8	265.90	
P 6 +	7	263.22	
Na 7 +	8	264.18	
Na 7 +	8	264.18	
Na 7 +	8	264.18	
Na 7 +	8	264.18	
Na 7 +	8	264.18	
Na 7 +	8	264.18	
Na 7 +	8	264.18	
Na 7 +	8	264.18	
Na 7 +	8	264.18	
Na 7 +	8	264.18	
Nd 3 +	3	22.10	216.99
Pm 3 +	3	22.30	216.79
Sm 3 +	3	23.40	215.69
Eu 3 +	3	24.90	214.19
Gd 3 +	3	20.63	218.46
Tb 3 +	3	21.91	217.18
Dy 3 +	3	22.80	216.29
Ho 3 +	3	22.84	216.25
Er 3 +	3	22.74	216.35
Tm 3 +	3	23.68	215.41
Yb 3 +	3	25.03	214.06
Lu 3 +	3	20.96	218.13
Hf 3 +	3	23.30	215.79
Pt 2 +	2	18.56	220.53
Au 2 +	2	20.50	218.59
Hg 2 +	2	18.76	220.33
Tl 2 +	2	20.43	218.66
Na 1 +	1	5.14	219.80
Na 1 +	1	5.14	215.29
Na 2 +	2	47.29	216.89
Na 2 +	2	47.29	218.61
Na 2 +	2	47.29	215.93
Na 2 +	2	47.29	216.89
Si 4 +	4	45.14	219.04
S 4 +	4	47.30	216.88
K 3 +	3	45.72	218.46
Ti 4 +	4	43.27	220.91
V 4 +	4	46.71	217.47
Cr 4 +	4	49.10	215.08
Ge 4 +	4	45.71	218.47
As 4 +	4	50.13	214.05
Br 4 +	4	47.30	216.88
Sr 3 +	3	43.60	220.58
Mo 4 +	4	46.40	217.78
Sb 4 +	4	44.20	219.98
La 4 +	4	49.95	214.23

Na 7 +	8	264.18	Gd 4 +	4	44.00	220.18
Na 7 +	8	264.18	Yb 4 +	4	43.70	220.48
Na 7 +	8	264.18	Lu 4 +	4	45.19	218.99
Na 7 +	8	264.18	Bi 4 +	4	45.30	218.88
Mg 6 +	7	224.94	Mg 1 +	1	7.65	217.29
S 7 +	8	328.23	Mg 4 +	4	109.24	218.99
Mg 6 +	7	224.94	Mg 1 +	1	7.65	217.29
Mg 6 +	7	224.94	Al 1 +	1	5.99	218.95
Mg 6 +	7	224.94	Si 1 +	1	8.15	216.79
Mg 6 +	7	224.94	P 1 +	1	10.49	214.45
Mg 6 +	7	224.94	S 1 +	1	10.36	214.58
Mg 6 +	7	224.94	K 1 +	1	4.34	220.60
Mg 6 +	7	224.94	Ca 1 +	1	6.11	218.83
Mg 6 +	7	224.94	Sc 1 +	1	6.54	218.40
Mg 6 +	7	224.94	Ti 1 +	1	6.82	218.12
Mg 6 +	7	224.94	V 1 +	1	6.74	218.20
Mg 6 +	7	224.94	Cr 1 +	1	6.77	218.17
Mg 6 +	7	224.94	Mn 1 +	1	7.43	217.51
Mg 6 +	7	224.94	Fe 1 +	1	7.87	217.07
Mg 6 +	7	224.94	Co 1 +	1	7.86	217.08
Mg 6 +	7	224.94	Ni 1 +	1	7.64	217.31
Mg 6 +	7	224.94	Cu 1 +	1	7.73	217.21
Mg 6 +	7	224.94	Zn 1 +	1	9.39	215.55
Mg 6 +	7	224.94	Ga 1 +	1	6.00	218.94
Mg 6 +	7	224.94	Ge 1 +	1	7.90	217.04
Mg 6 +	7	224.94	As 1 +	1	9.81	215.13
Mg 6 +	7	224.94	Se 1 +	1	9.75	215.19
Mg 6 +	7	224.94	Rb 1 +	1	4.18	220.76
Mg 6 +	7	224.94	Sr 1 +	1	5.70	219.24
Mg 6 +	7	224.94	Y 1 +	1	6.38	218.56
Mg 6 +	7	224.94	Zr 1 +	1	6.84	218.10
Mg 6 +	7	224.94	Nb 1 +	1	6.88	218.06
Mg 6 +	7	224.94	Mo 1 +	1	7.10	217.84
Mg 6 +	7	224.94	Tc 1 +	1	7.28	217.66
Mg 6 +	7	224.94	Ru 1 +	1	7.37	217.57
Mg 6 +	7	224.94	Rh 1 +	1	7.46	217.48

	Mg 6 +	7	224.94	Pd 1 +	1	8.34	216.60
	Mg 6 +	7	224.94	Ag 1 +	1	7.58	217.36
	Mg 6 +	7	224.94	Cd 1 +	1	8.99	215.95
	Mg 6 +	7	224.94	In 1 +	1	5.79	219.15
5	Mg 6 +	7	224.94	Sn 1 +	1	7.34	217.60
	Mg 6 +	7	224.94	Sb 1 +	1	8.64	216.30
	Mg 6 +	7	224.94	Te 1 +	1	9.01	215.93
	Mg 6 +	7	224.94	I 1 +	1	10.45	214.49
	Mg 6 +	7	224.94	Ba 1 +	1	5.21	219.73
10	Mg 6 +	7	224.94	Ba 2 +	2	10.00	214.94
	Mg 6 +	7	224.94	La 1 +	1	5.58	219.36
	Mg 6 +	7	224.94	Ce 1 +	1	5.47	219.47
	Mg 6 +	7	224.94	Ce 2 +	2	10.85	214.09
	Mg 6 +	7	224.94	Pr 1 +	1	5.42	219.52
15	Mg 6 +	7	224.94	Pr 2 +	2	10.55	214.39
	Mg 6 +	7	224.94	Nd 1 +	1	5.49	219.45
	Mg 6 +	7	224.94	Nd 2 +	2	10.73	214.21
	Mg 6 +	7	224.94	Pm 1 +	1	5.55	219.39
	Mg 6 +	7	224.94	Pm 2 +	2	10.90	214.04
20	Mg 6 +	7	224.94	Sm 1 +	1	5.63	219.31
	Mg 6 +	7	224.94	Eu 1 +	1	5.67	219.27
	Mg 6 +	7	224.94	Gd 1 +	1	6.14	218.80
	Mg 6 +	7	224.94	Tb 1 +	1	5.85	219.09
	Mg 6 +	7	224.94	Dy 1 +	1	5.93	219.01
25	Mg 6 +	7	224.94	Ho 1 +	1	6.02	218.92
	Mg 6 +	7	224.94	Er 1 +	1	6.10	218.84
	Mg 6 +	7	224.94	Tm 1 +	1	6.18	218.76
	Mg 6 +	7	224.94	Yb 1 +	1	6.25	218.69
	Mg 6 +	7	224.94	Lu 1 +	1	5.43	219.51
30	Mg 6 +	7	224.94	Hf 1 +	1	6.60	218.34
	Mg 6 +	7	224.94	Ta 1 +	1	7.89	217.05
	Mg 6 +	7	224.94	W 1 +	1	7.98	216.96
	Mg 6 +	7	224.94	Re 1 +	1	7.88	217.06
	Mg 6 +	7	224.94	Os 1 +	1	8.70	216.24
35	Mg 6 +	7	224.94	Ir 1 +	1	9.10	215.84
	Mg 6 +	7	224.94	Pt 1 +	1	9.00	215.94

	Mg 6 +	7	224.94	Au 1 +	1	9.23	215.71
	Mg 6 +	7	224.94	Hg 1 +	1	10.44	214.50
	Mg 6 +	7	224.94	Tl 1 +	1	6.11	218.83
	Mg 6 +	7	224.94	Pb 1 +	1	7.42	217.52
5	Mg 6 +	7	224.94	Bi 1 +	1	7.29	217.65
	Mg 6 +	7	224.94	Po 1 +	1	8.42	216.52
	Mg 6 +	7	224.94	Rn 1 +	1	10.75	214.19
	Mg 6 +	7	224.94	Ra 1 +	1	5.28	219.66
	Mg 6 +	7	224.94	Ra 2 +	2	10.15	214.79
10	Mg 6 +	7	224.94	Ac 1 +	1	5.20	219.74
	Mg 6 +	7	224.94	Th 1 +	1	6.10	218.84
	Mg 6 +	7	224.94	Pa 1 +	1	5.90	219.04
	Mg 6 +	7	224.94	U 1 +	1	6.05	218.89
	Mg 6 +	7	224.94	Np 1 +	1	6.20	218.74
15	Mg 6 +	7	224.94	Pu 1 +	1	6.06	218.88
	Mg 6 +	7	224.94	Am 1 +	1	5.99	218.95
	Mg 6 +	7	224.94	Cm 1 +	1	6.02	218.92
	Mg 6 +	7	224.94	Bk 1 +	1	6.23	218.71
	Mg 6 +	7	224.94	Cf 1 +	1	6.30	218.64
20	Mg 6 +	7	224.94	Es 1 +	1	6.42	218.52
	Mg 7 +	8	265.90	Si 4 +	4	45.14	220.76
	Mg 7 +	8	265.90	P 4 +	4	51.37	214.53
	Mg 7 +	8	265.90	S 4 +	4	47.30	218.60
	Mg 7 +	8	265.90	K 3 +	3	45.72	220.18
25	Mg 7 +	8	265.90	Ca 3 +	3	50.91	214.99
	Mg 7 +	8	265.90	V 4 +	4	46.71	219.19
	Mg 7 +	8	265.90	Cr 4 +	4	49.10	216.80
	Mg 7 +	8	265.90	Mn 4 +	4	51.20	214.70
	Mg 7 +	8	265.90	Co 4 +	4	51.30	214.60
30	Mg 7 +	8	265.90	Ge 4 +	4	45.71	220.19
	Mg 7 +	8	265.90	As 4 +	4	50.13	215.77
	Mg 7 +	8	265.90	Br 4 +	4	47.30	218.60
	Mg 7 +	8	265.90	Nb 5 +	5	50.55	215.35
	Mg 7 +	8	265.90	Mo 4 +	4	46.40	219.50
35	Mg 7 +	8	265.90	La 4 +	4	49.95	215.95
	Mg 7 +	8	265.90	Lu 4 +	4	45.19	220.71

Mg 7 +	8	265.90		Bi 4 +	4	45.30	220.60
P 5 +	6	220.43		Al 1 +	1	5.99	214.44
Si 6 +	7	246.52		Al 3 +	3	28.45	218.07
Al 6 +	7	241.43		S 2 +	2	23.33	218.10
Al 6 +	7	241.43		Cl 2 +	2	23.81	217.62
Al 6 +	7	241.43		Sc 3 +	3	24.76	216.67
Al 6 +	7	241.43		Ga 2 +	2	20.51	220.92
Al 6 +	7	241.43		Se 2 +	2	21.19	220.24
Al 6 +	7	241.43		Br 2 +	2	21.80	219.63
Al 6 +	7	241.43		Kr 2 +	2	24.36	217.07
Al 6 +	7	241.43		Rb 2 +	2	27.28	214.15
Al 6 +	7	241.43		Y 3 +	3	20.52	220.91
Al 6 +	7	241.43		Zr 3 +	3	22.99	218.44
Al 6 +	7	241.43		Nb 3 +	3	25.04	216.39
Al 6 +	7	241.43		Mo 3 +	3	27.16	214.27
Al 6 +	7	241.43		Ag 2 +	2	21.49	219.94
Al 6 +	7	241.43		Sb 3 +	3	25.30	216.13
Al 6 +	7	241.43		Xe 2 +	2	21.21	220.22
Al 6 +	7	241.43		Cs 2 +	2	25.10	216.33
Al 6 +	7	241.43		Pr 3 +	3	21.62	219.81
Al 6 +	7	241.43		Nd 3 +	3	22.10	219.33
Al 6 +	7	241.43		Pm 3 +	3	22.30	219.13
Al 6 +	7	241.43		Sm 3 +	3	23.40	218.03
Al 6 +	7	241.43		Eu 3 +	3	24.90	216.53
Al 6 +	7	241.43		Gd 3 +	3	20.63	220.80
Al 6 +	7	241.43		Tb 3 +	3	21.91	219.52
Al 6 +	7	241.43		Dy 3 +	3	22.80	218.63
Al 6 +	7	241.43		Ho 3 +	3	22.84	218.59
Al 6 +	7	241.43		Er 3 +	3	22.74	218.69
Al 6 +	7	241.43		Tm 3 +	3	23.68	217.75
Al 6 +	7	241.43		Yb 3 +	3	25.03	216.40
Al 6 +	7	241.43		Lu 3 +	3	20.96	220.47
Al 6 +	7	241.43		Hf 3 +	3	23.30	218.13
Al 6 +	7	241.43		Au 2 +	2	20.50	220.93
Al 6 +	7	241.43		Bi 3 +	3	25.56	215.87
Al 7 +	8	284.59		P 5 +	5	65.02	219.57

	Al 7 +	8	284.59	Cl 5 +	5	67.80	216.79
	Al 7 +	8	284.59	Ca 4 +	4	67.10	217.49
	Al 7 +	8	284.59	V 5 +	5	65.23	219.36
	Al 7 +	8	284.59	Cr 5 +	5	69.30	215.29
5	Al 7 +	8	284.59	Ga 4 +	4	64.00	220.59
	Al 7 +	8	284.59	As 5 +	5	63.63	220.96
	Al 7 +	8	284.59	Se 5 +	5	68.30	216.29
	Al 7 +	8	284.59	Kr 5 +	5	64.70	219.89
	Al 7 +	8	284.59	Mo 6 +	6	68.00	216.59
10	Al 7 +	8	284.59	Pb 5 +	5	68.80	215.79
	P 6 +	7	263.22	Si 4 +	4	45.14	218.08
	Si 6 +	7	246.52	P 3 +	3	30.18	216.34
	Si 6 +	7	246.52	Ar 2 +	2	27.63	218.89
	Si 6 +	7	246.52	K 2 +	2	31.63	214.90
15	Si 6 +	7	246.52	Ti 3 +	3	27.49	219.03
	Si 6 +	7	246.52	V 3 +	3	29.31	217.21
	Si 6 +	7	246.52	Cr 3 +	3	30.96	215.56
	Si 6 +	7	246.52	Fe 3 +	3	30.65	215.87
	Si 6 +	7	246.52	Ga 3 +	3	30.71	215.81
20	Si 6 +	7	246.52	As 3 +	3	28.35	218.17
	Si 6 +	7	246.52	Se 3 +	3	30.82	215.70
	Si 6 +	7	246.52	Rb 2 +	2	27.28	219.24
	Si 6 +	7	246.52	Mo 3 +	3	27.16	219.36
	Si 6 +	7	246.52	Tc 3 +	3	29.54	216.98
25	Si 6 +	7	246.52	Ru 3 +	3	28.47	218.05
	Si 6 +	7	246.52	Rh 3 +	3	31.06	215.46
	Si 6 +	7	246.52	In 3 +	3	28.03	218.49
	Si 6 +	7	246.52	Sn 3 +	3	30.50	216.02
	Si 6 +	7	246.52	Te 3 +	3	27.96	218.56
30	Si 6 +	7	246.52	Xe 3 +	3	32.10	214.42
	Si 6 +	7	246.52	Tl 3 +	3	29.83	216.69
	Si 6 +	7	246.52	Pb 3 +	3	31.94	214.58
	Si 6 +	7	246.52	Bi 3 +	3	25.56	220.96
	Si 7 +	8	303.17	S 6 +	6	88.05	215.12
35	Si 7 +	8	303.17	K 5 +	5	82.66	220.51
	Si 7 +	8	303.17	Ca 5 +	5	84.41	218.76

	Si 7 +	8	303.17	Zn 5 +	5	82.60	220.57
	Si 7 +	8	303.17	Br 6 +	6	88.60	214.57
	Si 7 +	8	303.17	Rb 6 +	6	84.40	218.77
	Si 7 +	8	303.17	Bi 6 +	6	88.30	214.87
5	S 6 +	7	280.93	P 5 +	5	65.02	215.91
	P 5 +	6	220.43	K 1 +	1	4.34	216.09
	P 5 +	6	220.43	Ca 1 +	1	6.11	214.32
	P 5 +	6	220.43	Ga 1 +	1	6.00	214.43
	P 5 +	6	220.43	Rb 1 +	1	4.18	216.25
10	P 5 +	6	220.43	Sr 1 +	1	5.70	214.73
	P 5 +	6	220.43	Y 1 +	1	6.38	214.05
	P 5 +	6	220.43	In 1 +	1	5.79	214.64
	P 5 +	6	220.43	Cs 1 +	1	3.89	216.54
	P 5 +	6	220.43	Ba 1 +	1	5.21	215.22
15	P 5 +	6	220.43	La 1 +	1	5.58	214.85
	P 5 +	6	220.43	Ce 1 +	1	5.47	214.96
	P 5 +	6	220.43	Pr 1 +	1	5.42	215.01
	P 5 +	6	220.43	Nd 1 +	1	5.49	214.94
	P 5 +	6	220.43	Pm 1 +	1	5.55	214.88
20	P 5 +	6	220.43	Sm 1 +	1	5.63	214.80
	P 5 +	6	220.43	Eu 1 +	1	5.67	214.76
	P 5 +	6	220.43	Gd 1 +	1	6.14	214.29
	P 5 +	6	220.43	Tb 1 +	1	5.85	214.58
	P 5 +	6	220.43	Dy 1 +	1	5.93	214.50
25	P 5 +	6	220.43	Ho 1 +	1	6.02	214.41
	P 5 +	6	220.43	Er 1 +	1	6.10	214.33
	P 5 +	6	220.43	Tm 1 +	1	6.18	214.25
	P 5 +	6	220.43	Yb 1 +	1	6.25	214.18
	P 5 +	6	220.43	Lu 1 +	1	5.43	215.00
30	P 5 +	6	220.43	Tl 1 +	1	6.11	214.32
	P 5 +	6	220.43	Ra 1 +	1	5.28	215.15
	P 5 +	6	220.43	Ac 1 +	1	5.20	215.23
	P 5 +	6	220.43	Th 1 +	1	6.10	214.33
	P 5 +	6	220.43	Pa 1 +	1	5.90	214.53
35	P 5 +	6	220.43	U 1 +	1	6.05	214.38
	P 5 +	6	220.43	Np 1 +	1	6.20	214.23

	P 5 +	6	220.43	Pu 1 +	1	6.06	214.37
	P 5 +	6	220.43	Am 1 +	1	5.99	214.44
	P 5 +	6	220.43	Cm 1 +	1	6.02	214.41
	P 5 +	6	220.43	Bk 1 +	1	6.23	214.20
5	P 5 +	6	220.43	Cf 1 +	1	6.30	214.13
	P 5 +	6	220.43	Es 1 +	1	6.42	214.01
	P 6 +	7	263.22	S 4 +	4	47.30	215.92
	P 6 +	7	263.22	K 3 +	3	45.72	217.50
	P 6 +	7	263.22	Ti 4 +	4	43.27	219.95
10	P 6 +	7	263.22	V 4 +	4	46.71	216.51
	P 6 +	7	263.22	Cr 4 +	4	49.10	214.12
	P 6 +	7	263.22	Ge 4 +	4	45.71	217.51
	P 6 +	7	263.22	Se 4 +	4	42.94	220.28
	P 6 +	7	263.22	Br 4 +	4	47.30	215.92
15	P 6 +	7	263.22	Sr 3 +	3	43.60	219.62
	P 6 +	7	263.22	Mo 4 +	4	46.40	216.82
	P 6 +	7	263.22	Sb 4 +	4	44.20	219.02
	P 6 +	7	263.22	Eu 4 +	4	42.60	220.62
	P 6 +	7	263.22	Gd 4 +	4	44.00	219.22
20	P 6 +	7	263.22	Ho 4 +	4	42.50	220.72
	P 6 +	7	263.22	Er 4 +	4	42.60	220.62
	P 6 +	7	263.22	Tm 4 +	4	42.70	220.52
	P 6 +	7	263.22	Yb 4 +	4	43.70	219.52
	P 6 +	7	263.22	Lu 4 +	4	45.19	218.03
25	P 6 +	7	263.22	Pb 4 +	4	42.32	220.90
	P 6 +	7	263.22	Bi 4 +	4	45.30	217.92
	P 7 +	8	309.41	Ar 6 +	6	91.01	218.40
	P 7 +	8	309.41	Sc 5 +	5	91.66	217.75
	P 7 +	8	309.41	Cr 6 +	6	90.56	218.85
30	P 7 +	8	309.41	Mn 6 +	6	95.00	214.41
	P 7 +	8	309.41	Ge 5 +	5	93.50	215.91
	P 7 +	8	309.41	Br 6 +	6	88.60	220.81
	P 7 +	8	309.41	Sr 6 +	6	90.80	218.61
	P 7 +	8	309.41	Y 6 +	6	93.00	216.41
35	S 6 +	7	280.93	K 4 +	4	60.91	220.02
	S 6 +	7	280.93	V 5 +	5	65.23	215.70

S 6 +	7	280.93	Ga 4 +	4	64.00	216.93
S 6 +	7	280.93	As 5 +	5	63.63	217.30
S 6 +	7	280.93	Kr 5 +	5	64.70	216.23
S 6 +	7	280.93	Y 4 +	4	61.80	219.13
S 6 +	7	280.93	Mo 5 +	5	61.20	219.73
S 7 +	8	328.23	Cl 7 +	7	114.19	214.04
S 7 +	8	328.23	Ca 6 +	6	108.78	219.45
S 7 +	8	328.23	Sc 6 +	6	111.10	217.13
S 7 +	8	328.23	Ni 6 +	6	108.00	220.23
S 7 +	8	328.23	Zn 6 +	6	108.00	220.23
S 7 +	8	328.23	Kr 7 +	7	111.00	217.23
S 7 +	8	328.23	Sb 6 +	6	108.00	220.23
Cl 7 +	8	348.28	Ca 7 +	7	127.70	220.58
Cl 7 +	8	348.28	V 6 +	6	128.12	220.16
Cl 7 +	8	348.28	Co 7 +	7	129.00	219.28
Cl 7 +	8	348.28	Ni 7 +	7	133.00	215.28
Cl 7 +	8	348.28	Zn 7 +	7	134.00	214.28
Cl 7 +	8	348.28	As 6 +	6	127.60	220.68
Cl 7 +	8	348.28	Y 8 +	8	129.00	219.28

n = 54 (resonance shrinkage energy is given by $\frac{n}{2}$ 27.21 eV; with n = 54, the resonance shrinkage energy is 734.67)

Atom Oxidized	n	nth Ionization Energy (eV)	Atom Reduced	n	nth Ionization Energy (eV)	Energy Hole (eV)
O 6 +	7	739.32	Li 1 +	1	5.39	733.92
F 7 +	8	953.89	Be 4 +	4	217.71	736.17
O 6 +	7	739.32	B 1 +	1	8.30	731.02
O 7 +	8	871.39	O 6 +	6	138.12	733.27
O 6 +	7	739.32	Na 1 +	1	5.14	734.18
O 6 +	7	739.32	Mg 1 +	1	7.65	731.67
O 6 +	7	739.32	Al 1 +	1	5.99	733.33
O 6 +	7	739.32	Si 1 +	1	8.15	731.16
O 6 +	7	739.32	K 1 +	1	4.34	734.97
O 6 +	7	739.32	Ca 1 +	1	6.11	733.20

	O 6+	7	739.32	Sc 1 +	1	6.54	732.78
	O 6+	7	739.32	Ti 1 +	1	6.82	732.49
	O 6+	7	739.32	V 1 +	1	6.74	732.58
	O 6+	7	739.32	Cr 1 +	1	6.77	732.55
5	O 6+	7	739.32	Mn 1 +	1	7.43	731.88
	O 6+	7	739.32	Fe 1 +	1	7.87	731.45
	O 6+	7	739.32	Co 1 +	1	7.86	731.46
	O 6+	7	739.32	Ni 1 +	1	7.64	731.68
	O 6+	7	739.32	Cu 1 +	1	7.73	731.59
10	O 6+	7	739.32	Ga 1 +	1	6.00	733.32
	O 6+	7	739.32	Ge 1 +	1	7.90	731.42
	O 6+	7	739.32	Rb 1 +	1	4.18	735.14
	O 6+	7	739.32	Sr 1 +	1	5.70	733.62
	O 6+	7	739.32	Y 1 +	1	6.38	732.93
15	O 6+	7	739.32	Zr 1 +	1	6.84	732.47
	O 6+	7	739.32	Nb 1 +	1	6.88	732.43
	O 6+	7	739.32	Mo 1 +	1	7.10	732.22
	O 6+	7	739.32	Tc 1 +	1	7.28	732.03
	O 6+	7	739.32	Ru 1 +	1	7.37	731.95
20	O 6+	7	739.32	Rh 1 +	1	7.46	731.85
	O 6+	7	739.32	Pd 1 +	1	8.34	730.97
	O 6+	7	739.32	Ag 1 +	1	7.58	731.74
	O 6+	7	739.32	Cd 1 +	1	8.99	730.32
	O 6+	7	739.32	In 1 +	1	5.79	733.53
25	O 6+	7	739.32	Sn 1 +	1	7.34	731.97
	O 6+	7	739.32	Sb 1 +	1	8.64	730.67
	O 6+	7	739.32	Te 1 +	1	9.01	730.31
	O 6+	7	739.32	Cs 1 +	1	3.89	735.42
	O 6+	7	739.32	Ba 1 +	1	5.21	734.10
30	O 6+	7	739.32	La 1 +	1	5.58	733.74
	O 6+	7	739.32	Ce 1 +	1	5.47	733.85
	O 6+	7	739.32	Pr 1 +	1	5.42	733.89
	O 6+	7	739.32	Nd 1 +	1	5.49	733.83
	O 6+	7	739.32	Pm 1 +	1	5.55	733.76
35	O 6+	7	739.32	Sm 1 +	1	5.63	733.68
	O 6+	7	739.32	Eu 1 +	1	5.67	733.65

O 6 +	7	739.32	Gd 1 +	1	6.14	733.17
O 6 +	7	739.32	Tb 1 +	1	5.85	733.47
O 6 +	7	739.32	Dy 1 +	1	5.93	733.39
O 6 +	7	739.32	Ho 1 +	1	6.02	733.29
O 6 +	7	739.32	Er 1 +	1	6.10	733.22
O 6 +	7	739.32	Tm 1 +	1	6.18	733.13
O 6 +	7	739.32	Yb 1 +	1	6.25	733.06
O 6 +	7	739.32	Lu 1 +	1	5.43	733.89
O 6 +	7	739.32	Hf 1 +	1	6.60	732.72
O 6 +	7	739.32	Ta 1 +	1	7.89	731.42
O 6 +	7	739.32	W 1 +	1	7.98	731.34
O 6 +	7	739.32	Re 1 +	1	7.88	731.43
O 6 +	7	739.32	Os 1 +	1	8.70	730.61
O 6 +	7	739.32	Ir 1 +	1	9.10	730.22
O 6 +	7	739.32	Pt 1 +	1	9.00	730.32
O 6 +	7	739.32	Au 1 +	1	9.23	730.09
O 6 +	7	739.32	Tl 1 +	1	6.11	733.21
O 6 +	7	739.32	Pb 1 +	1	7.42	731.90
O 6 +	7	739.32	Bi 1 +	1	7.29	732.03
O 6 +	7	739.32	Po 1 +	1	8.42	730.90
O 6 +	7	739.32	Ra 1 +	1	5.28	734.04
O 6 +	7	739.32	Ac 1 +	1	5.20	734.11
O 6 +	7	739.32	Th 1 +	1	6.10	733.22
O 6 +	7	739.32	Pa 1 +	1	5.90	733.41
O 6 +	7	739.32	U 1 +	1	6.05	733.27
O 6 +	7	739.32	Np 1 +	1	6.20	733.11
O 6 +	7	739.32	Pu 1 +	1	6.06	733.26
O 6 +	7	739.32	Am 1 +	1	5.99	733.33
O 6 +	7	739.32	Cm 1 +	1	6.02	733.29
O 6 +	7	739.32	Bk 1 +	1	6.23	733.09
O 6 +	7	739.32	Cf 1 +	1	6.30	733.02
O 6 +	7	739.32	Es 1 +	1	6.42	732.90
O 7 +	8	871.39	O 6 +	6	138.12	733.27
O 7 +	8	871.39	Na 5 +	5	138.39	733.00
O 7 +	8	871.39	Mg 5 +	5	141.26	730.13
O 7 +	8	871.39	Sc 7 +	7	138.00	733.39

	O 7 +	8	871.39	Ti 7 +	7	140.80	730.59
	O 7 +	8	871.39	Cu 7 +	7	139.00	732.39
	O 7 +	8	871.39	Zn 7 +	7	134.00	737.39
	O 7 +	8	871.39	Rb 8 +	8	136.00	735.39
	O 7 +	8	871.39	Te 7 +	7	137.00	734.39
	F 7 +	8	953.89	P 6 +	6	220.43	733.46

Two-ion couples capable of producing energy holes for shrinking deuterium atoms involving cations and anions. The number in the column following the ion, (n), is the nth ionization energy of the atom. For example, Ga^{2+} + 30.71 eV = Ga^{3+} + e^- and H + e^- = H^- + 3.08 eV.

Atom Oxidized	n	nth Ionization Energy (eV)	Atom Reduced	n	nth Ionization Energy (eV)	Energy Hole (eV)
As 2 +	3	28.35	H	- 1	0.80	27.55
Ru 2 +	3	28.47	H	- 1	0.80	27.67
In 2 +	3	28.03	H	- 1	0.80	27.23
Te 2 +	3	27.96	H	- 1	0.80	27.16
Al 2 +	3	28.45	H	- 1	0.80	27.65
Ar 1 +	2	27.63	H	- 1	0.80	26.83
As 2 +	3	28.35	Li	- 1	0.61	27.74
Ru 2 +	3	28.47	Li	- 1	0.61	27.86
In 2 +	3	28.03	Li	- 1	0.61	27.42
Te 2 +	3	27.96	Li	- 1	0.61	27.35
Al 2 +	3	28.45	Li	- 1	0.61	27.84
Ar 1 +	2	27.63	Li	- 1	0.61	27.02
Ti 2 +	3	27.49	Li	- 1	0.61	26.88
As 2 +	3	28.35	B	- 1	0.30	28.05
Rb 1 +	2	27.28	B	- 1	0.30	26.98
Mo 2 +	3	27.16	B	- 1	0.30	26.86
Ru 2 +	3	28.47	B	- 1	0.30	28.17
In 2 +	3	28.03	B	- 1	0.30	27.73
Te 2 +	3	27.96	B	- 1	0.30	27.66
Al 2 +	3	28.45	B	- 1	0.30	28.15
Ar 1 +	2	27.63	B	- 1	0.30	27.33
Ti 2 +	3	27.49	B	- 1	0.30	27.19

	As 2 +	3	28.35	C	- 1	1.12	27.23
	Tc 2 +	3	29.54	C	- 1	1.12	28.42
	Ru 2 +	3	28.47	C	- 1	1.12	27.35
	In 2 +	3	28.03	C	- 1	1.12	26.91
5	Te 2 +	3	27.96	C	- 1	1.12	26.84
	N 1 +	2	29.60	C	- 1	1.12	28.48
	Al 2 +	3	28.45	C	- 1	1.12	27.33
	V 2 +	3	29.31	C	- 1	1.12	28.19
	As 2 +	3	28.35	O	- 1	1.47	26.89
10	Tc 2 +	3	29.54	O	- 1	1.47	28.07
	Ru 2 +	3	28.47	O	- 1	1.47	27.00
	Tl 2 +	3	29.83	O	- 1	1.47	28.36
	N 1 +	2	29.60	O	- 1	1.47	28.14
	Al 2 +	3	28.45	O	- 1	1.47	26.98
15	V 2 +	3	29.31	O	- 1	1.47	27.84
	Ga 2 +	3	30.71	F	- 1	3.45	27.26
	Se 2 +	3	30.82	F	- 1	3.45	27.37
	Rh 2 +	3	31.06	F	- 1	3.45	27.61
	Sn 2 +	3	30.50	F	- 1	3.45	27.05
20	Pb 2 +	3	31.94	F	- 1	3.45	28.49
	K 1 +	2	31.63	F	- 1	3.45	28.18
	Cr 2 +	3	30.96	F	- 1	3.45	27.51
	Fe 2	3	30.65	F	- 1	3.45	27.20
	As 2 +	3	28.35	Na	- 1	0.52	27.83
25	Ru 2 +	3	28.47	Na	- 1	0.52	27.95
	In 2 +	3	28.03	Na	- 1	0.52	27.51
	Te 2 +	3	27.96	Na	- 1	0.52	27.44
	Al 2 +	3	28.45	Na	- 1	0.52	27.93
	Ar 1 +	2	27.63	Na	- 1	0.52	27.11
30	Ti 2 +	3	27.49	Na	- 1	0.52	26.97
	As 2 +	3	28.35	Al	- 1	0.52	27.83
	Ru 2 +	3	28.47	Al	- 1	0.52	27.95
	In 2 +	3	28.03	Al	- 1	0.52	27.51
	Te 2 +	3	27.96	Al	- 1	0.52	27.44
35	Al 2 +	3	28.45	Al	- 1	0.52	27.93
	Ar 1 +	2	27.63	Al	- 1	0.52	27.11

	Ti 2 +	3	27.49	Al	- 1	0.52	26.97
	As 2 +	3	28.35	Si	- 1	1.39	26.96
	Tc 2 +	3	29.54	Si	- 1	1.39	28.15
	Ru 2 +	3	28.47	Si	- 1	1.39	27.08
5	Tl 2 +	3	29.83	Si	- 1	1.39	28.44
	N 1 +	2	29.60	Si	- 1	1.39	28.21
	Al 2 +	3	28.45	Si	- 1	1.39	27.06
	V 2 +	3	29.31	Si	- 1	1.39	27.92
	As 2 +	3	28.35	P	- 1	0.78	27.57
10	Ru 2 +	3	28.47	P	- 1	0.78	27.69
	In 2 +	3	28.03	P	- 1	0.78	27.25
	Te 2 +	3	27.96	P	- 1	0.78	27.18
	Al 2 +	3	28.45	P	- 1	0.78	27.67
	Ar 1 +	2	27.63	P	- 1	0.78	26.85
15	Tc 2 +	3	29.54	S	- 1	2.07	27.47
	Sn 2 +	3	30.50	S	- 1	2.07	28.43
	Tl 2 +	3	29.83	S	- 1	2.07	27.76
	N 1 +	2	29.60	S	- 1	2.07	27.53
	P 2 +	3	30.18	S	- 1	2.07	28.11
20	V 2 +	3	29.31	S	- 1	2.07	27.24
	Ga 2 +	3	30.71	Cl	- 1	3.61	27.10
	Se 2 +	3	30.82	Cl	- 1	3.61	27.21
	Rh 2 +	3	31.06	Cl	- 1	3.61	27.45
	Sn 2 +	3	30.50	Cl	- 1	3.61	26.89
25	Xe 2 +	3	32.10	Cl	- 1	3.61	28.49
	Pb 2 +	3	31.94	Cl	- 1	3.61	28.32
	K 1 +	2	31.63	Cl	- 1	3.61	28.01
	Cr 2 +	3	30.96	Cl	- 1	3.61	27.35
	Fe 2 +	3	30.65	Cl	- 1	3.61	27.04
30	As 2 +	3	28.35	K	- 1	0.69	27.66
	Ru 2 +	3	28.47	K	- 1	0.69	27.78
	In 2 +	3	28.03	K	- 1	0.69	27.34
	Te 2 +	3	27.96	K	- 1	0.69	27.27
	Al 2 +	3	28.45	K	- 1	0.69	27.75
35	Ar 1 +	2	27.63	K	- 1	0.69	26.93
	As 2 +	3	28.35	Fe	- 1	0.56	27.79

	Ru 2 +	3	28.47	Fe	- 1	0.56	27.91
	In 2 +	3	28.03	Fe	- 1	0.56	27.47
	Te 2 +	3	27.96	Fe	- 1	0.56	27.40
	Al 2 +	3	28.45	Fe	- 1	0.56	27.89
5	Ar 1 +	2	27.63	Fe	- 1	0.56	27.07
	Ti 2 +	3	27.49	Fe	- 1	0.56	26.93
	As 2 +	3	28.35	Co	- 1	0.95	27.40
	Ru 2 +	3	28.47	Co	- 1	0.95	27.52
	In 2 +	3	28.03	Co	- 1	0.95	27.08
10	Te 2 +	3	27.96	Co	- 1	0.95	27.01
	Al 2 +	3	28.45	Co	- 1	0.95	27.49
	V 2 +	3	29.31	Co	- 1	0.95	28.36
	Tc 2 +	3	29.54	Cu	- 1	1.82	27.72
	Tl 2 +	3	29.83	Cu	- 1	1.82	28.01
15	N 1 +	2	29.60	Cu	- 1	1.82	27.78
	P 2 +	3	30.18	Cu	- 1	1.82	28.36
	V 2 +	3	29.31	Cu	- 1	1.82	27.49
	Ga 2 +	3	30.71	Br	- 1	3.36	27.35
	Se 2 +	3	30.82	Br	- 1	3.36	27.46
20	Rh 2 +	3	31.06	Br	- 1	3.36	27.70
	Sn 2 +	3	30.50	Br	- 1	3.36	27.14
	P 2 +	3	30.18	Br	- 1	3.36	26.82
	K 1 +	2	31.63	Br	- 1	3.36	28.26
	Cr 2 +	3	30.96	Br	- 1	3.36	27.60
25	Fe 2 +	3	30.65	Br	- 1	3.36	27.29
	As 2 +	3	28.35	Rb	- 1	0.30	28.05
	Rb 1 +	2	27.28	Rb	- 1	0.30	26.98
	Mo 2 +	3	27.16	Rb	- 1	0.30	26.86
	Ru 2 +	3	28.47	Rb	- 1	0.30	28.17
30	In 2 +	3	28.03	Rb	- 1	0.30	27.73
	Te 2 +	3	27.96	Rb	- 1	0.30	27.66
	Al 2 +	3	28.45	Rb	- 1	0.30	28.15
	Ar 1 +	2	27.63	Rb	- 1	0.30	27.33
	Ti 2 +	3	27.49	Rb	- 1	0.30	27.19
35	Ga 2 +	3	30.71	I	- 1	3.06	27.65
	Se 2 +	3	30.82	I	- 1	3.06	27.76

Rh	2 +	3	31.06	I	- 1	3.06	28.00
Sn	2 +	3	30.50	I	- 1	3.06	27.44
P	2 +	3	30.18	I	- 1	3.06	27.12
Cr	2 +	3	30.96	I	- 1	3.06	27.90
Fe	2 +	3	30.65	I	- 1	3.06	27.59
As	2 +	3	28.35	Cs	- 1	0.30	28.05
Rb	1 +	2	27.28	Cs	- 1	0.30	26.98
Mo	2 +	3	27.16	Cs	- 1	0.30	26.86
Ru	2 +	3	28.47	Cs	- 1	0.30	28.17
In	2 +	3	28.03	Cs	- 1	0.30	27.73
Te	2 +	3	27.96	Cs	- 1	0.30	27.66
Al	2 +	3	28.45	Cs	- 1	0.30	28.15
Ar	1 +	2	27.63	Cs	- 1	0.30	27.33
Ti	2 +	3	27.49	Cs	- 1	0.30	27.19
Tc	2 +	3	29.54	Se	- 1	1.70	27.84
Tl	2 +	3	29.83	Se	- 1	1.70	28.13
N	1 +	2	29.60	Se	- 1	1.70	27.90
P	2 +	3	30.18	Se	- 1	1.70	28.48
V	2 +	3	29.31	Se	- 1	1.70	27.61
Tc	2 +	3	29.54	Te	- 1	2.20	27.34
Sn	2 +	3	30.50	Te	- 1	2.20	28.30
Tl	2 +	3	29.83	Te	- 1	2.20	27.63
N	1 +	2	29.60	Te	- 1	2.20	27.40
P	2 +	3	30.18	Te	- 1	2.20	27.98
V	2 +	3	29.31	Te	- 1	2.20	27.11
Fe	2 +	3	30.65	Te	- 1	2.20	28.45
As	2 +	3	28.35	As	- 1	0.60	27.75
Ru	2 +	3	28.47	As	- 1	0.60	27.87
In	2 +	3	28.03	As	- 1	0.60	27.43
Te	2 +	3	27.96	As	- 1	0.60	27.36
Al	2 +	3	28.45	As	- 1	0.60	27.85
Ar	1 +	2	27.63	As	- 1	0.60	27.03
Ti	2 +	3	27.49	As	- 1	0.60	26.89
Tc	2 +	3	29.54	Sb	- 1	2.00	27.54
Tl	2 +	3	29.83	Sb	- 1	2.00	27.83
N	1 +	2	29.60	Sb	- 1	2.00	27.60

	P 2 +	3	30.18	Sb	- 1	2.00	28.18
	V 2 +	3	29.31	Sb	- 1	2.00	27.31
	As 2 +	3	28.35	Bi	- 1	0.70	27.65
	Ru 2 +	3	28.47	Bi	- 1	0.70	27.77
5	In 2 +	3	28.03	Bi	- 1	0.70	27.33
	Te 2 +	3	27.96	Bi	- 1	0.70	27.26
	Al 2 +	3	28.45	Bi	- 1	0.70	27.75
	Ar 1 +	2	27.63	Bi	- 1	0.70	26.93
	Tc 2 +	3	29.54	Tl	- 1	2.10	27.44
10	Sn 2 +	3	30.50	Tl	- 1	2.10	28.40
	Tl 2 +	3	29.83	Tl	- 1	2.10	27.73
	N 1 +	2	29.60	Tl	- 1	2.10	27.50
	P 2 +	3	30.18	Tl	- 1	2.10	28.08
	V 2 +	3	29.31	Tl	- 1	2.10	27.21
15	Tc 2 +	3	29.54	Au	- 1	2.10	27.44
	Sn 2 +	3	30.50	Au	- 1	2.10	28.40
	Tl 2 +	3	29.83	Au	- 1	2.10	27.73
	N 1 +	2	29.60	Au	- 1	2.10	27.50
	P 2 +	3	30.18	Au	- 1	2.10	28.08
20	V 2 +	3	29.31	Au	- 1	2.10	27.21
	As 2 +	3	28.35	Hg	- 1	1.54	26.81
	Tc 2 +	3	29.54	Hg	- 1	1.54	28.00
	Ru 2 +	3	28.47	Hg	- 1	1.54	26.93
	Tl 2 +	3	29.83	Hg	- 1	1.54	28.29
25	N 1 +	2	29.60	Hg	- 1	1.54	28.06
	Al 2 +	3	28.45	Hg	- 1	1.54	26.91
	V 2 +	3	29.31	Hg	- 1	1.54	27.77
	As 2 +	3	28.35	As	- 1	0.60	27.75
	Ru 2 +	3	28.47	As	- 1	0.60	27.87
30	In 2 +	3	28.03	As	- 1	0.60	27.43
	Te 2 +	3	27.96	As	- 1	0.60	27.36
	Al 2 +	3	28.45	As	- 1	0.60	27.85
	Ar 1 +	2	27.63	As	- 1	0.60	27.03
	Ti 2 +	3	27.49	As	- 1	0.60	26.89
35	As 2 +	3	28.35	Ce	- 1	1.20	27.15
	Tc 2 +	3	29.54	Ce	- 1	1.20	28.34

	Ru 2 +	3	28.47	Ce	- 1	1.20	27.27
	In 2 +	3	28.03	Ce	- 1	1.20	26.83
	N 1 +	2	29.60	Ce	- 1	1.20	28.40
	Al 2 +	3	28.45	Ce	- 1	1.20	27.25
5	V 2 +	3	29.31	Ce	- 1	1.20	28.11
	As 2 +	3	28.35	Fr	- 1	0.46	27.89
	Rb 1 +	2	27.28	Fr	- 1	0.46	26.82
	Ru 2 +	3	28.47	Fr	- 1	0.46	28.01
	In 2 +	3	28.03	Fr	- 1	0.46	27.57
10	Te 2 +	3	27.96	Fr	- 1	0.46	27.50
	Al 2 +	3	28.45	Fr	- 1	0.46	27.99
	Ar 1 +	2	27.63	Fr	- 1	0.46	27.17
	Ti 2 +	3	27.49	Fr	- 1	0.46	27.03
	As 2 +	3	28.35	Ge	- 1	1.20	27.15
15	Tc 2 +	3	29.54	Ge	- 1	1.20	28.34
	Ru 2 +	3	28.47	Ge	- 1	1.20	27.27
	In 2 +	3	28.03	Ge	- 1	1.20	26.83
	N 1 +	2	29.60	Ge	- 1	1.20	28.40
	Al 2 +	3	28.45	Ge	- 1	1.20	27.25
20	V 2 +	3	29.31	Ge	- 1	1.20	28.11
	As 2 +	3	28.35	Sn	- 1	1.25	27.10
	Tc 2 +	3	29.54	Sn	- 1	1.25	28.29
	Ru 2 +	3	28.47	Sn	- 1	1.25	27.22
	N 1 +	2	29.60	Sn	- 1	1.25	28.35
25	Al 2 +	3	28.45	Sn	- 1	1.25	27.20
	V 2 +	3	29.31	Sn	- 1	1.25	28.06
	As 2 +	3	28.35	Pb	- 1	1.05	27.30
	Tc 2 +	3	29.54	Pb	- 1	1.05	28.49
	Ru 2 +	3	28.47	Pb	- 1	1.05	27.42
30	In 2 +	3	28.03	Pb	- 1	1.05	26.98
	Te 2 +	3	27.96	Pb	- 1	1.05	26.91
	Al 2 +	3	28.45	Pb	- 1	1.05	27.40
	V 2 +	3	29.31	Pb	- 1	1.05	28.26
	Tc 2 +	3	29.54	Po	- 1	1.80	27.74
35	Tl 2 +	3	29.83	Po	- 1	1.80	28.03
	N 1 +	2	29.60	Po	- 1	1.80	27.80

	P 2 +	3	30.18	Po	- 1	1.80	28.38
	V 2 +	3	29.31	Po	- 1	1.80	27.51
	Ga 2 +	3	30.71	At	- 1	2.80	27.91
	Se 2 +	3	30.82	At	- 1	2.80	28.02
5	Rh 2 +	3	31.06	At	- 1	2.80	28.26
	Sn 2 +	3	30.50	At	- 1	2.80	27.70
	Tl 2 +	3	29.83	At	- 1	2.80	27.03
	N 1 +	2	29.60	At	- 1	2.80	26.80
	P 2 +	3	30.18	At	- 1	2.80	27.38
10	Cr 2 +	3	30.96	At	- 1	2.80	28.16
	Fe 2 +	3	30.65	At	- 1	2.80	27.85
	As 2 +	3	28.35	Ge	- 1	1.20	27.15
	Tc 2 +	3	29.54	Ge	- 1	1.20	28.34
	Ru 2 +	3	28.47	Ge	- 1	1.20	27.27
15	In 2 +	3	28.03	Ge	- 1	1.20	26.83
	N 1 +	2	29.60	Ge	- 1	1.20	28.40
	Al 2 +	3	28.45	Ge	- 1	1.20	27.25
	V 2 +	3	29.31	Ge	- 1	1.20	28.11
	As 2 +	3	28.35	Ga	- 1	0.37	27.98
20	Rb 1 +	2	27.28	Ga	- 1	0.37	26.91
	Ru 2 +	3	28.47	Ga	- 1	0.37	28.10
	In 2 +	3	28.03	Ga	- 1	0.37	27.66
	Te 2 +	3	27.96	Ga	- 1	0.37	27.59
	Al 2 +	3	28.45	Ga	- 1	0.37	28.08
25	Ar 1 +	2	27.63	Ga	- 1	0.37	27.26
	Ti 2 +	3	27.49	Ga	- 1	0.37	27.12
	As 2 +	3	28.35	In	- 1	0.35	28.00
	Rb 1 +	2	27.28	In	- 1	0.35	26.93
	Mo 2 +	3	27.16	In	- 1	0.35	26.81
30	Ru 2 +	3	28.47	In	- 1	0.35	28.12
	In 2 +	3	28.03	In	- 1	0.35	27.68
	Te 2 +	3	27.96	In	- 1	0.35	27.61
	Al 2 +	3	28.45	In	- 1	0.35	28.10
	Ar 1 +	2	27.63	In	- 1	0.35	27.28
35	Ti 2 +	3	27.49	In	- 1	0.35	27.14
	As 2 +	3	28.35	Ag	- 1	1.30	27.05

Tc 2 +	3	29.54	Ag	- 1	1.30	28.24
Ru 2 +	3	28.47	Ag	- 1	1.30	27.17
N 1 +	2	29.60	Ag	- 1	1.30	28.30
Al 2 +	3	28.45	Ag	- 1	1.30	27.15
V 2 +	3	29.31	Ag	- 1	1.30	28.01

Cations and anions with n = 16 (resonance shrinkage energy is given by $\frac{n}{2}$ 27.21; with n = 16, the resonance shrinkage energy is 217.68)

Atom Oxidized	n	nth Ionization Energy (eV)	Atom Reduced	n	nth Ionization Energy (eV)	Energy Hole (eV)
Be 3 +	4	217.71	H	- 1	0.80	216.91
Be 3 +	4	217.71	Li	- 1	0.61	217.10
Be 3 +	4	217.71	B	- 1	0.30	217.41
Be 3 +	4	217.71	C	- 1	1.12	216.59
Be 3 +	4	217.71	O	- 1	1.47	216.25
P 5 +	6	220.43	O	- 1	1.47	218.96
P 5 +	6	220.43	F	- 1	3.45	216.98
Be 3 +	4	217.71	Na	- 1	0.52	217.19
Be 3 +	4	217.71	Al	- 1	0.52	217.19
Be 3 +	4	217.71	Si	- 1	1.39	216.32
Be 3 +	4	217.71	P	- 1	0.78	216.94
Be 3 +	4	217.71	S	- 1	2.07	215.64
P 5 +	6	220.43	S	- 1	2.07	218.36
P 5 +	6	220.43	Cl	- 1	3.61	216.82
Be 3 +	4	217.71	K	- 1	0.69	217.02
Be 3 +	4	217.71	Fe	- 1	0.56	217.15
Be 3 +	4	217.71	Co	- 1	0.95	216.76
Be 3 +	4	217.71	Cu	- 1	1.82	215.89
P 5 +	6	220.43	Cu	- 1	1.82	218.61
P 5 +	6	220.43	Br	- 1	3.36	217.07
Be 3 +	4	217.71	Rb	- 1	0.30	217.41
P 5 +	6	220.43	I	- 1	3.06	217.37
Be 3 +	4	217.71	Cs	- 1	0.30	217.41
Be 3 +	4	217.71	Se	- 1	1.70	216.01

	P 5 +	6	220.43	Se	- 1	1.70	218.73
	P 5 +	6	220.43	Te	- 1	2.20	218.23
	Be 3 +	4	217.71	As	- 1	0.60	217.11
	P 5 +	6	220.43	As	- 1	0.60	219.83
	P 5 +	6	220.43	Sb	- 1	2.00	218.43
	Be 3 +	4	217.71	Bi	- 1	0.70	217.01
	P 5 +	6	220.43	Bi	- 1	0.70	219.73
	P 5 +	6	220.43	Tl	- 1	2.10	218.33
	P 5 +	6	220.43	Au	- 1	2.10	218.33
	Be 3 +	4	217.71	Hg	- 1	1.54	216.17
	P 5 +	6	220.43	Hg	- 1	1.54	218.89
	Be 3 +	4	217.71	As	- 1	0.60	217.11
	P 5 +	6	220.43	As	- 1	0.60	219.83
	Be 3 +	4	217.71	Ce	- 1	1.20	216.51
	P 5 +	6	220.43	Ce	- 1	1.20	219.23
	Be 3 +	4	217.71	Fr	- 1	0.46	217.25
	P 5 +	6	220.43	Fr	- 1	0.46	219.97
	Be 3 +	4	217.71	Ge	- 1	1.20	216.51
	P 5 +	6	220.43	Ge	- 1	1.20	219.23
	Be 3 +	4	217.71	Sn	- 1	1.25	216.46
	P 5 +	6	220.43	Sn	- 1	1.25	219.18
	Be 3 +	4	217.71	Pb	- 1	1.05	216.66
	P 5 +	6	220.43	Pb	- 1	1.05	219.38
	P 5 +	6	220.43	Po	- 1	1.80	218.63
	P 5 +	6	220.43	At	- 1	2.80	217.63
	Be 3 +	4	217.71	Ge	- 1	1.20	216.51
	P 5 +	6	220.43	Ge	- 1	1.20	219.23
	Be 3 +	4	217.71	Ga	- 1	0.37	217.34
	Be 3 +	4	217.71	In	- 1	0.35	217.36
	Be 3 +	4	217.71	Ag	- 1	1.30	216.41
	P 5 +	6	220.43	Ag	- 1	1.30	219.13

Cations and anions with n = 54 (resonance shrinkage energy is given by $\frac{n}{2}$ 27.21; with n = 54, the resonance shrinkage energy is 734.67)

Atom Oxidiz-	n	nth Ion-ization	Atom Reduced	n	nth Ion-ization	Energy Hole

	ed		Energy (eV)			Energy (eV)	(eV)
	O 6+	7	739.32	H	- 1	0.80	738.52
	O 6+	7	739.32	Li	- 1	0.61	738.70
5	O 6+	7	739.32	C	- 1	1.12	738.20
	O 6+	7	739.32	O	- 1	1.47	737.85
	O 6+	7	739.32	F	- 1	3.45	735.87
	O 6+	7	739.32	Na	- 1	0.52	738.80
	O 6+	7	739.32	Al	- 1	0.52	738.80
10	O 6+	7	739.32	Si	- 1	1.39	737.93
	O 6+	7	739.32	P	- 1	0.78	738.54
	O 6+	7	739.32	S	- 1	2.07	737.24
	O 6+	7	739.32	Cl	- 1	3.61	735.70
	O 6+	7	739.32	K	- 1	0.69	738.62
15	O 6+	7	739.32	Fe	- 1	0.56	738.76
	O 6+	7	739.32	Co	- 1	0.95	738.36
	O 6+	7	739.32	Cu	- 1	1.82	737.49
	O 6+	7	739.32	Br	- 1	3.36	735.95
	O 6+	7	739.32	I	- 1	3.06	736.25
20	O 6+	7	739.32	Se	- 1	1.70	737.61
	O 6+	7	739.32	Te	- 1	2.20	737.11
	O 6+	7	739.32	As	- 1	0.60	738.72
	O 6+	7	739.32	Sb	- 1	2.00	737.32
	O 6+	7	739.32	Bi	- 1	0.70	738.61
25	O 6+	7	739.32	Tl	- 1	2.10	737.22
	O 6+	7	739.32	Au	- 1	2.10	737.22
	O 6+	7	739.32	Hg	- 1	1.54	737.78
	O 6+	7	739.32	As	- 1	0.60	738.72
	O 6+	7	739.32	Ce	- 1	1.20	738.11
30	O 6+	7	739.32	Fr	- 1	0.46	738.85
	O 6+	7	739.32	Ge	- 1	1.20	738.11
	O 6+	7	739.32	Sn	- 1	1.25	738.07
	O 6+	7	739.32	Pb	- 1	1.05	738.27
	O 6+	7	739.32	Po	- 1	1.80	737.52
35	O 6+	7	739.32	At	- 1	2.80	736.52
	O 6+	7	739.32	Ge	- 1	1.20	738.11

O 6 +	7	739.32	Ga	- 1	0.37	738.95
O 6 +	7	739.32	In	- 1	0.35	738.97
O 6 +	7	739.32	Ag	- 1	1.30	738.02

Some representative couples comprising a cation and a molecule capable of producing energy holes for shrinking deuterium atoms where the molecule is reduced. The number in the column following the ion or molecule, (n), is the nth ionization energy of the atom or molecule. For example, Ga^{2+} + 30.71 eV = Ga^{3+} + e^- and BF_3 + e^- = BF_3 + 2.65 eV.

Atom Oxidized	n	nth Ionization Energy (eV)	Atom Reduced	n	nth Ionization Energy (eV)	Energy Hole (eV)
Ga 2 +	3	30.71	BF_3	- 1	2.65	28.06
Se 2 +	3	30.82	BF_3	- 1	2.65	28.17
Tc 2 +	3	29.54	BF_3	- 1	2.65	26.89
Rh 2 +	3	31.06	BF_3	- 1	2.65	28.41
Sn 2 +	3	30.50	BF_3	- 1	2.65	27.85
Tl 2 +	3	29.83	BF_3	- 1	2.65	27.18
N 1 +	2	29.60	BF_3	- 1	2.65	26.95
P 2 +	3	30.18	BF_3	- 1	2.65	27.53
Cr 2 +	3	30.96	BF_3	- 1	2.65	28.31
Fe 2 +	3	30.65	BF_3	- 1	2.65	28.00
Se 2 +	3	30.82	NO_2	- 1	3.91	26.91
Rh 2 +	3	31.06	NO_2	- 1	3.91	27.15
Xe 2 +	3	32.10	NO_2	- 1	3.91	28.19
Pb 2 +	3	31.94	NO_2	- 1	3.91	28.03
K 1 +	2	31.63	NO_2	- 1	3.91	27.72
Cr 2 +	3	30.96	NO_2	- 1	3.91	27.05
As 2 +	3	28.35	O_2	- 1	0.45	27.90
Rb 1 +	2	27.28	O_2	- 1	0.45	26.83
Ru 2 +	3	28.47	O_2	- 1	0.45	28.02
In 2 +	3	28.03	O_2	- 1	0.45	27.58
Te 2 +	3	27.96	O_2	- 1	0.45	27.51
Al 2 +	3	28.45	O_2	- 1	0.45	28.00
Ar 1 +	2	27.63	O_2	- 1	0.45	27.18
Ti 2 +	3	27.49	O_2	- 1	0.45	27.04

	As 2 +	3	28.35	SF_6	- 1	1.43	26.92
	Tc 2 +	3	29.54	SF_6	- 1	1.43	28.11
	Ru 2 +	3	28.47	SF_6	- 1	1.43	27.04
	Tl 2 +	3	29.83	SF_6	- 1	1.43	28.40
5	N 1 +	2	29.60	SF_6	- 1	1.43	28.17
	Al 2 +	3	28.45	SF_6	- 1	1.43	27.02
	V 2 +	3	29.31	SF_6	- 1	1.43	27.88
	Ga 2 +	3	30.71	WF_6	- 1	2.74	27.97
	Se 2 +	3	30.82	WF_6	- 1	2.74	28.08
10	Tc 2 +	3	29.54	WF_6	- 1	2.74	26.80
	Rh 2 +	3	31.06	WF_6	- 1	2.74	28.32
	Sn 2 +	3	30.50	WF_6	- 1	2.74	27.76
	Tl 2 +	3	29.83	WF_6	- 1	2.74	27.09
	N 1 +	2	29.60	WF_6	- 1	2.74	26.86
15	P 2 +	3	30.18	WF_6	- 1	2.74	27.44
	Cr 2 +	3	30.96	WF_6	- 1	2.74	28.22
	Fe 2 +	3	30.65	WF_6	- 1	2.74	27.91
	Ga 2 +	3	30.71	UF_6	- 1	2.91	27.80
	Se 2 +	3	30.82	UF_6	- 1	2.91	27.91
20	Rh 2 +	3	31.06	UF_6	- 1	2.91	28.15
	Sn 2 +	3	30.50	UF_6	- 1	2.91	27.59
	Tl 2 +	3	29.83	UF_6	- 1	2.91	26.92
	P 2 +	3	30.18	UF_6	- 1	2.91	27.27
	Cr 2 +	3	30.96	UF_6	- 1	2.91	28.05
25	Fe 2 +	3	30.65	UF_6	- 1	2.91	27.74
	Tc 2 +	3	29.54	CF_3	- 1	1.85	27.69
	Tl 2 +	3	29.83	CF_3	- 1	1.85	27.98
	N 1 +	2	29.60	CF_3	- 1	1.85	27.75
	P 2 +	3	30.18	CF_3	- 1	1.85	28.33
30	V 2 +	3	29.31	CF_3	- 1	1.85	27.46
	As 2 +	3	28.35	CCl_3	- 1	1.22	27.13
	Tc 2 +	3	29.54	CCl_3	- 1	1.22	28.32
	Ru 2 +	3	28.47	CCl_3	- 1	1.22	27.25
	In 2 +	3	28.03	CCl_3	- 1	1.22	26.81
35	N 1 +	2	29.60	CCl_3	- 1	1.22	28.38
	Al 2 +	3	28.45	CCl_3	- 1	1.22	27.23

	V 2 +	3	29.31	CCl_3	- 1	1.22	28.09
	Ga 2 +	3	30.71	SiF_3	- 1	3.35	27.36
	Se 2 +	3	30.82	SiF_3	- 1	3.35	27.47
	Rh 2 +	3	31.06	SiF_3	- 1	3.35	27.71
5	Sn 2 +	3	30.50	SiF_3	- 1	3.35	27.15
	P 2 +	3	30.18	SiF_3	- 1	3.35	26.83
	K 1 +	2	31.63	SiF_3	- 1	3.35	28.27
	Cr 2 +	3	30.96	SiF_3	- 1	3.35	27.61
	Fe 2 +	3	30.65	SiF_3	- 1	3.35	27.30
10	As 2 +	3	28.35	NH_2	- 1	1.12	27.23
	Tc 2 +	3	29.54	NH_2	- 1	1.12	28.42
	Ru 2 +	3	28.47	NH_2	- 1	1.12	27.35
	In 2 +	3	28.03	NH_2	- 1	1.12	26.91
	Te 2 +	3	27.96	NH_2	- 1	1.12	26.84
15	N 1 +	2	29.60	NH_2	- 1	1.12	28.48
	Al 2 +	3	28.45	NH_2	- 1	1.12	27.33
	V 2 +	3	29.31	NH_2	- 1	1.12	28.19
	Tc 2 +	3	29.54	PH_2	- 1	1.60	27.94
	Ru 2 +	3	28.47	PH_2	- 1	1.60	26.87
20	Tl 2 +	3	29.83	PH_2	- 1	1.60	28.23
	N 1 +	2	29.60	PH_2	- 1	1.60	28.00
	Al 2 +	3	28.45	PH_2	- 1	1.60	26.85
	V 2 +	3	29.31	PH_2	- 1	1.60	27.71
	Tc 2 +	3	29.54	OH	- 1	1.83	27.71
25	Tl 2 +	3	29.83	OH	- 1	1.83	28.00
	N 1 +	2	29.60	OH	- 1	1.83	27.77
	P 2 +	3	30.18	OH	- 1	1.83	28.35
	V 2 +	3	29.31	OH	- 1	1.83	27.48
	Tc 2 +	3	29.54	SH	- 1	2.19	27.35
30	Sn 2 +	3	30.50	SH	- 1	2.19	28.31
	Tl 2 +	3	29.83	SH	- 1	2.19	27.64
	N 1 +	2	29.60	SH	- 1	2.19	27.41
	P 2 +	3	30.18	SH	- 1	2.19	27.99
	V 2 +	3	29.31	SH	- 1	2.19	27.12
35	Fe 2 +	3	30.65	SH	- 1	2.19	28.46
	Ga 2 +	3	30.71	CN	- 1	3.17	27.54

	Se 2 +	3	30.82	CN	- 1	3.17	27.65
	Rh 2 +	3	31.06	CN	- 1	3.17	27.89
	Sn 2 +	3	30.50	CN	- 1	3.17	27.33
	P 2 +	3	30.18	CN	- 1	3.17	27.01
	K 1 +	2	31.63	CN	- 1	3.17	28.45
	Cr 2 +	3	30.96	CN	- 1	3.17	27.79
	Fe 2 +	3	30.65	CN	- 1	3.17	27.48
	Tc 2 +	3	29.54	SCN	- 1	2.17	27.37
	Sn 2 +	3	30.50	SCN	- 1	2.17	28.33
	Tl 2 +	3	29.83	SCN	- 1	2.17	27.66
	N 1 +	2	29.60	SCN	- 1	2.17	27.43
	P 2 +	3	30.18	SCN	- 1	2.17	28.01
	V 2 +	3	29.31	SCN	- 1	2.17	27.14
	Fe 2 +	3	30.65	SCN	- 1	2.17	28.48
	Ga 2 +	3	30.71	SeCN	- 1	2.64	28.07
	Se 2 +	3	30.82	SeCN	- 1	2.64	28.18
	Tc 2 +	3	29.54	SeCN	- 1	2.64	26.90
	Rh 2 +	3	31.06	SeCN	- 1	2.64	28.42
	Sn 2 +	3	30.50	SeCN	- 1	2.64	27.86
	Tl 2 +	3	29.83	SeCN	- 1	2.64	27.19
	N 1 +	2	29.60	SeCN	- 1	2.64	26.96
	P 2 +	3	30.18	SeCN	- 1	2.64	27.54
	Cr 2 +	3	30.96	SeCN	- 1	2.64	28.32
	Fe 2 +	3	30.65	SeCN	- 1	2.64	28.01

Cations and molecular anions with n = 16 (resonance shrinkage energy is given by $\frac{n}{2}$ 27.21 with n = 16, the resonance shrinkage energy is 217.68)

Atom Oxidized	n	nth Ionization Energy (eV)	Atom Reduced	n	nth Ionization Energy (eV)	Energy Hole (eV)
P 5 +	6	220.43	BF_3	- 1	2.65	217.78
P 5 +	6	220.43	NO_2	- 1	3.91	216.52
Be 3 +	4	217.71	O_2	- 1	0.45	217.26
P 5 +	6	220.43	O_2	- 1	0.45	219.98
Be 3 +	4	217.71	SF_6	- 1	1.43	216.28

	P 5+	6	220.43	SF_6	- 1	1.43	219.00
	P 5+	6	220.43	WF_6	- 1	2.74	217.69
	P 5+	6	220.43	UF_6	- 1	2.91	217.52
	P 5+	6	220.43	CF_3	- 1	1.85	218.58
	Be 3+	4	217.71	CCl_3	- 1	1.22	216.49
	P 5+	6	220.43	CCl_3	- 1	1.22	219.21
	P 5+	6	220.43	SiF_3	- 1	3.35	217.08
	Be 3+	4	217.71	NH_2	- 1	1.12	216.59
	P 5+	6	220.43	NH_2	- 1	1.12	219.31
	Be 3+	4	217.71	PH_2	- 1	1.60	216.11
	P 5+	6	220.43	PH_2	- 1	1.60	218.83
	P 5+	6	220.43	OH	- 1	1.83	218.60
	P 5+	6	220.43	SH	- 1	2.19	218.24
	P 5+	6	220.43	CN	- 1	3.17	217.26
	P 5+	6	220.43	SCN	- 1	2.17	218.26
	P 5+	6	220.43	SeCN	- 1	2.64	217.79

Cations and molecular anions with n = 54 (resonance shrinkage energy is given by $\frac{n}{2}$ 27.21 with n = 54, the resonance shrinkage energy is 734.67)

Atom Oxidized	n	nth Ionization Energy (eV)	Atom Reduced	n	nth Ionization Energy (eV)	Energy Hole (eV)
O 6+	7	739.32	BF_3	- 1	2.65	736.66
O 6+	7	739.32	NO_2	- 1	3.91	735.41
O 6+	7	739.32	O_2	- 1	0.45	738.86
O 6+	7	739.32	SF_6	- 1	1.43	737.89
O 6+	7	739.32	WF_6	- 1	2.74	736.58
O 6+	7	739.32	UF_6	- 1	2.91	736.41
O 6+	7	739.32	CF_3	- 1	1.85	737.47
O 6+	7	739.32	CCl_3	- 1	1.22	738.10
O 6+	7	739.32	SiF_3	- 1	3.35	735.97
O 6+	7	739.32	NH_2	- 1	1.12	738.20
O 6+	7	739.32	PH_2	- 1	1.60	737.72
O 6+	7	739.32	OH	- 1	1.83	737.48
O 6+	7	739.32	SH	- 1	2.19	737.13

O 6+	7	739.32	CN	-1	3.17	736.15
O 6+	7	739.32	SCN	-1	2.17	737.15
O 6+	7	739.32	SeCN	-1	2.64	736.67

The fusion of deuterium to ^3He releases neutron which can effect the fusion of ^6Li to helium. In one embodiment of Coulombic Annihilation Fusion, ^6Li is present in the fusion reaction mixture of deuterium where fusion of deuterium further drives the fusion of ^6Li.

Other atoms in addition to deuterium can be caused to fuse by Coulombic Annihilation as described for deuterium.

The quantum of energy hole is calculated for the atoms involved and a reaction or process which removes this much energy and regenerates the atoms or molecules to be fused is effected until sufficient energy is removed from the Mills orbitals so that the internuclear distance is sufficient for the nuclear strong force to dominate the coulombic repulsive force. Fusion then occurs.

Fusion Reactor

The fusion reactor 50, shown in Figure 6 comprises a vessel 52 which contains the fusion reaction mixture 54, a heat exchanger 60, and a steam generator 62 where the heat exchanger 60 absorbs heat released by CAF and exchanges it with the steam generator 62 which absorbs heat from the exchanger 60 and produces steam. The fusion reactor 50 further comprises a turbine 70 which receives steam from the steam generator 62 and supplies mechanical power to a power generator 80 which converts the steam energy into electrical energy, which is received by a load 90 to produce work or for dissipation.

The fusion reaction mixture 54 comprises a source of deuterium atoms 56 or a source of molecular deuterium, and a source of energy holes 58 which resonantly remove $\frac{n}{2}$ 27.21 eV; n = 2, 3, 4,..., of energy from deuterium to effect shrinkage to the point of fusion. The source of deuterium can be deuterium gas, electrolysis of deuterium oxide, deuterium from hydrides, or deuterium from metal-deuterium solutions.

A source of energy holes comprises a catalytic energy hole material 58, typically comprising electrochemical couples including the catalytic couples described in the Coulombic Annihilation Fusion Section. Thus, an exemplary fusion reaction mixture is molecular deuterium a salt of Pd^{2+}

and a lithium$^+$ salt. Palladium absorbs molecular deuterium and the Pd^{2+}/Li^+ catalytic system effect resonant shrinkage of deuterium to the point of fusion. In one embodiment, the lithium is ^6Li in which case the neutrons released from fusion of deuterium effects the fusion of ^6Li to helium.

In other embodiments, the fusionable material is one of any element of the periodic chart, and the energy of the holes of the said source of energy holes is resonant with the Mills orbital shrinkage energy which is calculated using Mills mechanics of the present invention and described for deuterium in Appendix VI.

In the preferred embodiment, ^2H, ^3H, or ^6Li is used as the fusionable material.

In all embodiments, the source of energy holes is one or more of an electrochemical, chemical, photochemical, thermal, free radical, sonic, or nuclear reactions, inelastic photon or particle scattering reactions.

In the latter two cases, the present invention of a fusion reactor comprises a particle and/or photon source to supply the said energy holes.

In all reaction mixtures a selected external energy device 75, such as an electrode may be used to supply an electrostatic potential or a current to decrease the activation energy of the resonant absorption of an energy hole.

In another embodiment the fusion mixture 54, further comprises a surface or material to absorb atoms and/or molecules of the fusionable material 56. Such surfaces or materials to absorb deuterium, or tritium comprise transition elements and inner transition elements including iron, platinum, palladium, zirconium, vanadium, nickel, titanium, Sc, Cr, Mn, Co, Cu, Zn, Y, Nb, Mo, Tc, Ru, Rh, Ag, Cd, La, Hf, Ta, W, Re, Os, Ir, Au, Hg, Ce, Pr, Nd, Pm, Sm, Eu, Gd, Tb, Oy, Ho, Er, Tm, Yb, Lu, Th, Pa, and U.

Experimental

S. Pons, et al, have demonstrated cold fusion with an electrochemical cell that electrolyzes deuterium oxide to deuterium at a palladium electrode with lithium as the counter ion. That excess heat is released and that some fusion of deuterium is detectable is apparent by the present invention. The third ionization energy of palladium is 32.93 eV and the first ionization energy of lithium is 5.392 eV. This system can catalytically generate energy holes of

$$32.93 \text{ eV} - 5.392 \text{ eV} = 27.538 \text{ eV}$$

The catalytic reaction is given in the Coulombic Annihilation Fusion Section. The quantum of energy needed to decrease a Mills orbital by $a_o(\frac{1}{n_1} - \frac{1}{n_2})$ is 27.21 eV. The energy difference between 27.538 eV and 27.21 eV is carried by a phonon or a translational or rotational mode. CAF occurs at a slower rate when sodium or potassium is used as the electrolyte because the energy hole produced by the Pd^{2+}/Na^{+} system is 27.791 eV and the energy hole of the Pd^{2+}/K^{+} system is 28.589 eV.

The energy holes of the Pd^{2+}/Li^{+} system are closer to the resonance quantum of 27.21 eV. Thus, it is not surprising that lithium is a superior counter ion to effect CAF.

That cold fusion at a titanium electrode has been observed by S. E. Jones et al to proceed a faster rate than with the Pd^{2+}/ Li^{+} catalytic system is not surprising in that the catalytic reaction involves only one atom as the catalyst, and the third ionization energy of titanium is 27.491 eV which is close to the shrinkage quantum of 27.21 eV. The catalytic reaction appears in the Coulombic Annihilation Fusion Section.

27.21 eV of heat is released during a radius reducing cycle of the Mills orbital of the deuterium atom in the Pons and Jones systems. Approximately 100 KeV of heat energy is released by the shrinkage process before the nuclei approach sufficiently for fusion to occur. This heat is unaccountable by both research groups. Interestingly, this unaccountable heat was observed in electrochemical cells with palladium electrodes, Group I cation electrolytes; and aqueous solutions as long ago as 1924 by Jirsa (Jirsa, F., Z. Physik, Chem., 113, 241 (1924)). Thus, Pons and Jones' observation of the phenomenon of heat release due to resonant Mills orbital shrinkage is not the first.

Furthermore, physicist Francesco Scaramuzzi effected cold fusion of deuterium gas using shavings of titanium; whereas, in 1973, Catlett, et al., (Catlett, D. S., et al., The Journal of Chemical Physics, 58(8), p. 3432, (1973)) diffused deuterium gas into palladium and measured no fusion products by sensitive mass spectroscopy. According to the present model of the atom, CAF was catalyzed by Ti^{2+} in the former experiment, and CAF was not possible in the latter due to the absence of the second element of a two-element catalytic couple such as Li^{+} of the Pd^{2+}/Li^{+} couple.

Further Applications

Mills Mechanics, the present invention, is a means to derive a complete quantitative description of any atom, molecule, or material. The said descriptions can be used to device novel molecules, materials, and electronic devices; thus, they can eliminate much experimentation. And, they can be used to interpret the results of experimentation.

For any atom, the radii of all Mills orbitals are calculated using the balance of forces as described in the One Electron Section, the Two Electron Section, and the Three Electron Section. The orbital energies are then calculated as described in the said sections to give the complete mathematical description of any atom or ion. Thus, with the selection rules, described in the Section Rules Section, together with the orbital energies and the principle of conservation of energy, all transitions are given.

Bonding is calculated by minimizing the total energy stored in the electric and magnetic fields of the participating atoms as described in the Nature of the Chemical Bond Section. The resulting minimum for all atoms describes exactly any molecule or material. The physical properties can then be calculated from the following parameters:

1.) coordinates of the nuclei and Mills orbitals;
2.) the bond and orbital energies
3.) the bond energy as a function of said coordinates
4.) population of Mills orbitals (e.g., unpaired electron or two spin paired electrons in a given orbital)

Furthermore, Mills mechanics is a means to calculate reaction coordinates as energy surfaces that describe the intermediates of a reaction; thus, reaction mechanisms are given. With this knowledge, novel syntheses and products can be engineered, catalysts can be developed, and yields of the desired products increased. Also, phenomenon which occur too rapidly to be observed or have yet to be discovered (recent examples are cold fusion and high transition temperature superconductors) are described exactly via Mills mechanics which provides a complete description of matter on the atomic and molecular level.

Appendix I

Proof that the condition for radiation by a charge density function is that it possesses components of its space-time Fourier Transform which are synchronous with waves traveling at the speed of light is given. Charge obeys superposition; thus, only a point charge need be considered. The proof starts with the Fourier components of the current produced by the moving charge. The electric field is found from the vector wave equation in Fourier space (k, ω space). The inverse Fourier transform is carried over the magnitude of k. The resulting expression demonstrates that the radiation field is proportional to $\bar{J}_\perp(\frac{\omega}{c}\bar{n},\omega)$, where $\bar{J}_\perp(\bar{k},\omega)$ is the space-time Fourier transform of the current perpendicular to $\bar{k}$ and $\bar{n} \equiv \frac{\bar{k}}{|k|}$; thus, the necessary condition for radiation by the charge is that its space-time Fourier transform possesses components which travel at the speed of light.

II. The Source and Its Fourier Transforms

Consider a charged particle of charge q and position $\bar{r}_o(t)$. The charge density of the particle is described by

$$\rho(\bar{r}, t) = q\delta[\bar{r} - \bar{r}_o(t)] \qquad (2.1)$$

where $\delta(\bar{r} - \bar{r}_o)$ is the spatial unit impulse function. The current density is

$$\bar{J}(\bar{r}, t) = q\dot{\bar{r}}_o(t)\delta[\bar{r} - \bar{r}_o(t)] \quad . \qquad (2.2)$$

The spatial Fourier transform represents the current density as a superposition of spatial exponentials, $\exp -j\,\bar{k}\cdot\bar{r}$.

$$\bar{J}(\bar{k}, t) = \int\int\int d^3\bar{k}\, q\dot{\bar{r}}_o(t)\delta[\bar{r} - \bar{r}_o(t)]\, \exp(-i\,\bar{k}\cdot\bar{r}) \qquad (2.3)$$

$$= q\dot{\bar{r}}_o(t)\, \exp(-i\,\bar{k}\cdot\bar{r}_o)$$

The full space time Fourier transform is of course,

$$\bar{J}(\bar{k}, w) = \int\int\int\int dt d^3\bar{k}\ \bar{J}(\bar{r},t)\ \exp(-i\ \bar{k}\cdot\bar{r})\ \exp(i\omega t) \qquad (2.4)$$

The inverse Fourier transform is

$$\bar{J}(\bar{r}, t) = \left(\frac{1}{2\pi}\right)^4 \int d\omega \int\int\int d\bar{k}^3 \bar{J}(\bar{k},\omega)\ \exp(i\ \bar{k}\cdot\bar{r})\ \exp(-i\omega t) \qquad (2.5)$$

III. The Electromagnetic Field

The electric field obeys the vector wave equation

$$\nabla \times (\nabla \times \bar{E}) + \frac{1}{c^2}\frac{\delta^2\bar{E}}{\delta t^2} = -\mu_o\frac{\delta\bar{J}}{\delta t} \qquad (3.1)$$

The space-time Fourier transform of the vector wave equation is:

$$\bar{k} \times [\ \bar{k} \times \bar{E}(\bar{k},\omega)\ ] + \frac{\omega^2}{c^2}\bar{E}(k,\omega) = -i\omega\mu_o\bar{J}(\bar{k},\omega) \qquad (3.2)$$

In the far-field, only the component perpendicular to $\bar{k}$ is of interest. Concentrating on this component one has

$$\bar{E}_\perp(\bar{k},\omega) = \frac{-i\omega\mu_o\bar{n}\times[\bar{n}\times\bar{J}(\bar{k},\omega)]}{k^2 - \omega^2/c^2} \qquad (3.3)$$

with

$$\bar{n} = \frac{\bar{k}}{|k|} \qquad (3.4)$$

IV. The Inverse Spatial Fourier Transform

The inverse space-time Fourier transform involves the integrals

$$\int\frac{d\omega}{2\pi}\exp(-i\omega t)\left(\frac{1}{2\pi}\right)^3\iiint d^3\bar{k}\exp(i\bar{k}\cdot\bar{r})$$

We shall retain the Fourier transform with respect to time and thus not carry out the integration over ω. But we shall focus on a spectral width $d\omega$ of the field and thus write down expressions for $\bar{E}_\perp(\bar{r},\omega)\frac{d\omega}{2\pi}$. We

separate the integrals into an integral over the magnitude of $\bar{k}$, and into a double integral with respect to the angles θ and ϕ of $\bar{k}$ with respect to $\bar{r}$.

$$\bar{E}_{\perp}(\bar{r},\omega)\frac{d\omega}{2\pi} = -\frac{d\omega}{2\pi}\left(\frac{1}{2\pi}\right)^3 \iint d\phi d\theta \sin\theta$$

$$\int i\omega\mu_o k^2 dk \frac{\bar{n}x[\bar{n}x\bar{J}(\bar{k},\omega)]}{k^2 - \omega^2/c^2} \exp(i\bar{k}\cdot\bar{r}) \qquad (4.1)$$

The last integral can be carried out by contour integration. For $\bar{k}\cdot\bar{r} > 0$, the contour must be closed into the negative imaginary half plane of k with the result

$$\bar{E}_{\perp}(\bar{r},\omega)\frac{d\omega}{2\pi} = \left(\frac{1}{2\pi}\right)^2 \frac{\omega^2}{c^2} d\left(\frac{\omega}{c}\right) \iint \frac{d\phi d\theta \sin\theta}{4\pi}$$

$$\sqrt{\frac{\mu_o}{\varepsilon_o}}\, c\bar{n}x[\bar{n}x\bar{J}(\frac{\omega}{c}\bar{n},\omega)]\exp(i\frac{\omega}{c}\bar{n}\cdot\bar{r}) \qquad (4.2)$$

This expression may be rewritten in a way that lends itself to an appealing interpretation. The density of (linearly polarized) modes per unit volume and unit solid angle, $\rho(\omega,\Omega)$, is

$$\rho(\omega,\Omega) = d\omega d\Omega = \frac{1}{2\pi}\left(\frac{\omega}{c}\right)^2 d\left(\frac{\omega}{c}\right)\frac{d\Omega}{4\pi} \qquad (4.3)$$

With this definition, one has

$$\bar{E}_{\perp}(\bar{r},\omega)\frac{d\omega}{2\pi} = \frac{c}{2\pi}\int \rho(\omega,\Omega) d\omega d\Omega \sqrt{\frac{\mu_o}{\varepsilon_o}}$$

$$\bar{n}x[\bar{n}x\bar{J}(\frac{\omega}{c}\bar{n},\omega)]\exp(i\frac{\omega}{c}\bar{n}\cdot\bar{r}) \qquad (4.4)$$

The field $\bar{E}_{\perp}(\bar{r},\omega)\frac{d\omega}{2\pi}$ is proportional to $-\bar{J}(\frac{\omega}{c}\bar{n},\omega)$ namely, the Fourier component for which $k = \omega/c$. Factors of ω that multiply the Fourier component of the current are due to the density of modes per unit volume and unit solid angle. An unaccelerated charge does not radiate in free space, not because it experiences no acceleration, but because it has no

Fourier component.

$$\bar{J}(\frac{\omega}{c}\bar{n},\omega)$$

Indeed, from (2.3)

$$\bar{J}(\bar{k},\omega) = \int dt q\bar{v}\ \exp(-i\bar{k}\cdot\bar{v}t + i\omega t)$$

$$= 2\pi q\bar{v}\delta(\omega - \bar{k}\cdot\bar{v}) \qquad (4.5)$$

The only nonzero Fourier components are for

$$k = \frac{\omega}{v\cos\theta} > \frac{\omega}{c} \qquad (4.6)$$

where θ is the angle between $\bar{v}$ and $\bar{k}$. The reason for the radiation of an accelerated charge is that the Fourier decomposition of the current acquires Fourier components that are "synchronous" with the light velocity, i.e. with the propagation constant $|\bar{k}| = \frac{w}{c}$. Thus, for example, an oscillating charge

$$\bar{r}_o(t) = \bar{d}\ \sin\omega_o t \qquad (4.7)$$

has a Fourier spectrum

$$\bar{J}(\bar{k},\omega) = \frac{q\omega_o d}{2} J_m(k\cos\theta d)\{\delta[\omega - (m+1)\omega_o] + \delta[\omega - (m-1)\omega_o]\} \qquad (4.8)$$

where the Jm's are Bessel functions of order m. These Fourier components can, and do, acquire phase velocities that are equal to the light velocity. For small *kd* only $m = 0$ remains and is approximately independent of k, $J_o(\frac{\omega_o}{c}\cos\theta d) \cong 1$.

V. Integration Over Angles

Starting with (4.2), we note that the exponential is a strong function of θ whereas the component $\bar{n} \times [\bar{n} \times \bar{J}]$ varies much more slowly and thus can be pulled out from under the integration. We have to integrate an expression of the form

$$\frac{1}{2\pi}\frac{\omega^2 d\omega}{c^3}\int_0^{2\pi}\int_0^{\pi}\frac{d\phi d\theta \sin\theta}{4\pi}\exp(i\frac{\omega}{c}\cos\theta\cdot\bar{r}) = -\frac{1}{2}\,i\,\frac{\omega}{c^2 r}\frac{d\omega}{2\pi}\exp(i\frac{\omega}{c}\cdot\bar{r})$$

where the upper limit on θ is ignored because of the rapid variation of the exponent. With this result introduced in (4.2) one has

$$\bar{E}_{\perp}(\bar{r},\omega)\frac{d\omega}{2\pi} = \frac{d\omega}{2\pi}\frac{i}{4\pi}\sqrt{\frac{\mu_o}{\varepsilon_o}}\frac{\omega}{c\,r}\bar{n}x[\bar{n}x\bar{J}(\frac{\omega}{c}\bar{n},\omega)]\exp(i\frac{\omega}{c}\bar{n}\cdot\bar{r}) \qquad (5.1)$$

Here, $\bar{n}$ is the direction of the radius vector $\bar{r}$. We note now that a factor of ω appears in front of the current. One may therefore interpret the source as containing the acceleration where $-i\omega$ represents differentiation with respect to the time coordinate.

It seems more natural to attribute the factor to the integration over all the modes, in particular because then Cherenkov radiation presents less of a mystery. Cherenkov radiation is produced by an unaccelerated particle, but since the velocity of light is less than c, the particle current can have Fourier components synchronous with $\frac{\omega}{c}\sqrt{\frac{\epsilon}{\epsilon_o}}$ where ϵ is the dielectric constant of the medium.

Appendix II

Space-time Fourier transform of Mills orbitals.

The space-time Fourier transform in three dimensions in polar coordinates is given as follows:

$$G(s,\Theta,\Phi,\omega) = \int_0^{\infty}\int_0^{\pi}\int_0^{2\pi} g(r,\theta,\phi,t)\exp\{-i2\pi sr[\cos\Theta\cos\theta + \sin\Theta\sin\theta\cos(\phi-\Phi) + \frac{\omega}{2\pi}t]\}\, r^2\sin\theta\, dr\, d\theta\, d\phi\, dt$$

with circular symmetry.

$$G(s,\Theta) = 2\pi\int_0^{\infty}\int_0^{\pi} g(r,\theta)\, J_0(2\pi sr\sin\Theta\sin\theta)\exp\{-i2\pi sr\cos\Theta\cos\theta\}\, r^2\sin\theta\, dr\, d\theta$$

with spherical symmetry.

$$G(S) = 4\pi \int_0^{\infty} g(r)\, \mathrm{sinc}(2sr)\, r^2\, dr$$

For separable variables

$$f(r)\, g(\theta)\, h(\phi)\, k(t) \longleftrightarrow F(s)\, G(\Theta)\, H(\Phi)\, K(\omega)$$

Mills orbitals are separable into a product of functions of independent variables, r, θ , ϕ , and t. The radial functions are delta functions. The time functions are of the form $e^{i\omega t}$, the angular functions are spherical harmonics, sin or cosine trigonometric functions or sums of these functions, each raised to various powers. The space-time Fourier transform is derived of the separable variables for the angular space function of sin ϕ and sin θ. It follows from the space-time Fourier transform given below that other possible spherical harmonics angular functions give the same form of result as the transform of sin θ and sin ϕ.

The space Fourier transform of $f(r) = \delta(r-r_o)$ is given as follows:

$$F(S) = 4\pi \int_0^{\infty} \delta(r - r1)\, \mathrm{sinc}(2sr)\, r^2 dr$$

$$F(S) = 4\pi r_1^2\, \mathrm{sinc}(2s r_1)$$

The space Fourier transform of $g(\theta) = \sin\theta$ is given as follows where there is no dependence on ϕ:

$$G(\Theta) = 2\pi \int_0^{\infty} \int_0^{\pi} \sin\theta\, J_0(2\pi sr \sin\Theta \sin\theta) \exp(-i2\pi sr \cos\Theta \cos\theta) \sin\theta\, r^2\, d\theta\, dr$$

$$G(\Theta) = 2\pi \int_0^{\infty} \int_0^{\pi} r^2 \sin^2\theta \, J_0 (2\pi sr \sin\Theta \sin\theta) \cos (2\pi sr \cos\Theta \cos\theta) \, d\theta \, dr$$

$$J_\upsilon (z) = (\tfrac{1}{2} z)^\upsilon \sum_{n=0}^{\infty} \frac{(-1)^n (\frac{z}{2})^{2n}}{n! (\upsilon + n + 1)}$$

$$z = 2\pi sr \sin\Theta \sin\theta$$

$$G(\Theta) = 2\pi \int_0^{\infty} \int_0^{\pi} r^2 \sin^2\theta \left(\sum_{n=0}^{\infty} \frac{(-1)^n (\pi r \sin\Theta \sin\theta)^{2n}}{n! (n + 1)} \right) \cos(2\pi sr \cos\Theta \cos\theta) \, d\theta dr$$

$$G(\Theta) = 2\pi \int_0^{\infty} r^2 \int_0^{\pi} \sum_{n=0}^{\infty} \frac{(-1)^n (\pi r \sin\Theta)^{2n}}{n! (n + 1)} \sin\theta^{2(n+1)} \cos(2\pi sr \cos\Theta \cos\theta) \, d\theta dr$$

$$G(\Theta) = 2\pi \int_0^{\infty} r^2 \int_0^{\pi} \sum_{n=0}^{\infty} \frac{(-1)^{n-1} (\pi r \sin\Theta)^{2(n-1)}}{n (n - 1)!} \sin^{2n}\theta \cos(2\pi sr \cos\Theta \cos\theta) \, d\theta dr$$

$$J_\upsilon (z) = \frac{(\frac{z}{2})^\upsilon}{\Gamma(\frac{1}{2}) \Gamma(\upsilon + \frac{1}{2})} \int_0^{\pi} \cos(z \cos\theta) \sin^{2\upsilon}\theta \, d\theta$$

$R_e(\upsilon) > -(1/2)$, $z = 2\pi sr\cos\Theta$

$$G(\Theta) = 2\pi\int_0^\infty r^2 \sum_{\upsilon=1}^{\infty} \int_0^\pi \frac{(-1)^{\upsilon-1}(\pi r \sin\Theta)^{2(\upsilon-1)}}{\upsilon(\upsilon-1)!}$$

$$\frac{\Gamma(\frac{1}{2})\Gamma(\upsilon+\frac{1}{2})(\pi sr\cos\Theta)\upsilon}{(\pi sr\cos\Theta)\upsilon\Gamma(\frac{1}{2})\Gamma(\upsilon+\frac{1}{2})} \sin^{2\upsilon}\theta\cos(2\pi sr\cos\Theta\cos\theta)\,d\theta dr$$

$$G(\Theta) = 2\pi\int_0^\infty r^2 \sum_{\upsilon=1}^{\infty} \frac{(-1)^{\upsilon-1}(\pi r \sin\Theta)^{2(\upsilon-1)}}{\upsilon(\upsilon-1)!}$$

$$\frac{\Gamma(\frac{1}{2})\Gamma(\upsilon+\frac{1}{2})}{(\pi sr\cos\Theta)^\upsilon} \frac{(\pi sr\cos\Theta)^\upsilon}{\Gamma(\frac{1}{2})\Gamma(\upsilon+\frac{1}{2})} \int_0^\pi \sin^{2\upsilon}\theta\cos(2\pi sr\cos\Theta\cos\theta)d\theta dr$$

$$G(\Theta) = 2\pi\int_0^\infty r^2 \sum_{\upsilon=1}^{\infty} \int_0^\pi \frac{(-1)^{\upsilon-1}(\pi r \sin\Theta)^{2(\upsilon-1)}}{\upsilon(\upsilon-1)!}$$

$$\frac{\Gamma(\frac{1}{2})\Gamma(\upsilon+\frac{1}{2})}{(\pi sr\cos\Theta)^\upsilon} J_\upsilon(2\pi sr\cos\Theta)\,dr$$

Hankel transform formula:

$$\int_0^\infty r^{-(1/2)}(rs)^{(1/2)} J_\upsilon(rs)\,dr = s^{(1/2)}$$

Hankel transform relationship:

$$f(x) \longleftrightarrow g(y;\nu) = \int_0^\infty f(x)\,(xy)^{(1/2)} J_\nu(xy)\,dx$$

$$x^m f(x),\ m = 0, 1, 2\ldots \longleftrightarrow y^{(1/2)-\nu}\left(\frac{d}{y\,dy}\right)^m \left[\, y^{(m+\nu-1/2)} g(y;\, m+\nu)\right]$$

$$\int_0^\infty r^\nu\, r^{-(1/2)}\,(rs)^{(1/2)}\, J_\nu(rs)\,dr = s^{(1/2)-\nu}\left(\frac{d}{s\,ds}\right)^\nu \left[\, s^{\nu+\nu-(1/2)}\, s^{(1/2)}\right]$$

$$\int_0^\infty r^\nu\, s^{(1/2)}\, J_\nu(rs)\,dr = \frac{s^{1/2-\nu}}{s^\nu}\left(\frac{d}{ds}\right)^\nu \left[\, s^{2\nu}\right]$$

$$\int_0^\infty r^\nu\, s^{(1/2)}\, J_\nu(rs)\,dr = s^{(1/2)-2\nu}\,\frac{2\nu!}{\nu!}\,s^\nu = \frac{2\nu!}{\nu!}\,s^{(1/2)-\nu}$$

$$\int_0^\infty r^\nu\, s^{-(1/2)} s^{(1/2)} J_\nu(rs)\,dr = \frac{2\nu!}{\nu!}\,s^{-\nu}$$

$$g(\Theta) = 2\pi \sum_{\nu=1}^{\infty} \int_0^\infty \frac{(-1)^{\nu-1}(\pi\,s\ln\Theta)^{2(\nu-1)}}{\nu\,(\nu-1)!} \frac{\Gamma\left(\frac{1}{2}\right)\Gamma\left(\nu+\frac{1}{2}\right)}{(\pi s\cos\Theta)^\nu}\, r^\nu J_\nu(2\pi s r\cos\Theta)\,dr$$

$$\text{let } r = \frac{r'}{2\pi\cos\Theta} \qquad dr = \frac{dr'}{2\pi\cos\Theta}$$

$$g(\Theta) = 2\pi \sum_{\nu=1}^{\infty} \int_0^\infty \frac{(-1)^{\nu-1}(\pi\,s\ln\Theta)^{2(\nu-1)}}{\nu\,(\nu-1)!} \frac{\Gamma\left(\frac{1}{2}\right)\Gamma\left(\nu+\frac{1}{2}\right)}{(\pi s\cos\Theta)^\nu} \frac{r^\nu}{(2\pi\cos\Theta)^{\nu+1}}\, J(sr')\,dr'$$

$$g(\Theta) = 2\pi \sum_{\nu=1}^{\infty} \frac{(-1)^{\nu-1}(\pi\,s\ln\Theta)^{2(\nu-1)}}{\nu\,(\nu-1)!}$$

$$\frac{\Gamma(\frac{1}{2})\Gamma(\upsilon+\frac{1}{2})}{(\pi s\cos\Theta)^{\upsilon}(2\pi\cos\Theta)^{\upsilon+1}}\ \frac{2\upsilon!}{\upsilon!}\,s^{-\upsilon}$$

$$G(\Theta) = 2\pi\sum_{\upsilon=1}^{\infty}\frac{(-1)^{\upsilon-1}(\pi\sin\Theta)^{2(\upsilon-1)}}{\upsilon\,(\upsilon-1)!}\ \frac{\Gamma(\frac{1}{2})\Gamma(\upsilon+\frac{1}{2})}{(\pi\cos\Theta)^{2\upsilon+1}2^{\upsilon+1}}\ \frac{2\upsilon!}{\upsilon!}\,s^{-2\upsilon}$$

The space Fourier transform of $h(\phi) = \sin\phi$ is given as follows where there is no dependence on θ:

Apply change of variable to the Fourier transform of $g(\theta) = \sin\theta$.

$$\theta \Longrightarrow \phi \quad \text{implies} \quad \Theta \Longrightarrow \Phi$$

$$\therefore H(\Phi) = \sum_{\upsilon=1}^{\infty}\frac{(-1)^{\upsilon-1}(\pi\sin\Phi)^{2(\upsilon-1)}}{\upsilon\,(\upsilon-1)!}\ \frac{\Gamma(\frac{1}{2})\Gamma(\upsilon+\frac{1}{2})}{(\pi\cos\Theta)^{2\upsilon+1}2^{\upsilon+1}}\ \frac{2\upsilon!}{\upsilon!}\,s^{-2\upsilon}$$

The time Fourier transform of $K(t)=\mathrm{Re}(\exp(j\omega_1 t))$ is given as follows:

$$\int_0^{\infty}\cos\omega_0 t\,\exp(-\kappa\omega t)\,dt = \frac{1}{2\pi}\frac{1}{2}\left[\delta(\omega-\omega_1)+\delta(\omega+\omega_1)\right]$$

The space-time Fourier transform of a Mills orbital is of the following form:

$$M(s,\Theta,\Phi,\omega) = \Gamma(s)\,G(\Theta)\,H(\Phi)\,K(\omega)$$

$$M(s, \Theta, \Phi, \omega) = 4\pi r_1^2 \operatorname{sinc}(2sr_1) \sum_{\upsilon=1}^{\infty} \frac{(-1)^{\upsilon-1}(\pi \sin\Theta)^{2(\upsilon-1)}}{\upsilon(\upsilon-1)!}$$

$$\frac{\Gamma(\frac{1}{2})\Gamma(\upsilon+\frac{1}{2})}{2^{\upsilon+1}(\pi\cos\Theta)^{2\upsilon+1}} \frac{2\upsilon!}{\upsilon!} s^{-2\upsilon}$$

$$\sum_{\upsilon=1}^{\infty} \frac{(-1)^{\upsilon-1}(\pi \sin\Phi)^{2(\upsilon-1)}}{\upsilon(\upsilon-1)!} \frac{\Gamma(\frac{1}{2})\Gamma(\upsilon+\frac{1}{2})}{2^{\upsilon+1}(\pi\cos\Theta)^{2\upsilon+1}} \frac{2\upsilon!}{\upsilon!} s^{-2\upsilon}$$

$$\frac{1}{4\pi}[\delta(\omega-\omega_0)+\delta(\omega+\omega_1)]$$

The condition for radiation of a charge density function is given in Appendix I. The space-time Fourier transform of the charge density function must not have waves synchronous with waves traveling at the speed of light, that is synchronous with $\frac{\omega_n}{c}$ or synchronous with $\frac{\omega_n}{c}\sqrt{\frac{\epsilon}{\epsilon_o}}$ where ϵ is the dielectric constant of the medium. Given the angular velocity, $\omega = \omega_n$, the space-time Fourier transform of the Mills orbital is zero for

$$s = \frac{2\pi}{\lambda_n} \quad \text{when} \tag{II.1}$$

$$2\pi(nr_1) = 2\pi r_n = n\lambda_1 = \lambda_n \tag{II.2}$$

where $n = 1$

$n = 2, 3, 4, \ldots$

$n = \frac{1}{2}, \frac{1}{3}, \frac{1}{4}, \ldots$

λ_1 is the allowed wavelength for $n = 1$

r_1 is the allowed radius for $n = 1$

Thus, space-time harmonics of $\frac{\omega_n}{c} = k$ or $\frac{\omega_n}{c}\sqrt{\frac{\epsilon}{\epsilon_o}} = k$ do not exist. Thus, radiation due to charge motion does not occur in any medium when this boundary condition is met.

Appendix III

The solution to the Schrodinger equation is a wave function ψ (x). An interpretation of ψ (x) is required. Schrodinger postulated that ψ (x) represents the amplitude of the particle in some sense, and because the intensity of a wave is the square of the amplitude the "intensity of the particle" is proportional to $\psi^*(x)\,\psi(x)$ [$\psi^*(x)$ is the complex conjugate of ψ (x)]. A controversy arose over the meaning of intensity. Schrodinger considered $e\,\psi^*(x)\,\psi(x)$ to be the charge density or $e\,\psi^*(x)\,\psi(x)$ to be the amount of charge between x and x + dx. Thus, he presumed the electron to be spread all over the region.

The electron has kinetic energy and angular momentum and energy must be conserved; thus, the motion of an electron must be time harmonic.

It is demonstrated in Appendix I that emission of electromagnetic radiation occurs if the space-time Fourier transform possesses waves that are light synchronous with waves traveling at the speed of light. It is demonstrated below that the Schrodinger wave equations have such components; thus, they must radiate. That no radiation is observed demonstrates the invalidity of these equations as an accurate description of an electron.

The angular functions of Schrodinger wave equations are spherical harmonics and their space-time Fourier transform is given in Appendix II as the transforms of $g(\theta)$, $h(\phi)$, and $k(t)$. The radial solutions are of the form of a r raised to a power times a negative exponential of r. The space-time Fourier transform of the radial function $f(r) = re^{-r/a_0}$ follows:

$$\int_0^\infty re^{-(r/a_0)}\,\mathrm{sinc}(2sr)\,r^2\,dr$$

$$\int_0^\infty r^3 e^{-(r/a_0)}\,\frac{\sin 2\pi(2sr)\,dr}{\pi 2sr}$$

$$\int_0^\infty (r^2 e^{-(r/a_0)})/(2\pi s)\,\sin 4\pi sr\,dr$$

Let $r = r'/4\pi$, $dr' = (1/4\pi)\,dr$

$$\frac{1}{4\pi}\int_0^{\infty} \frac{r'^2}{(4\pi)^2 2\pi s} \exp\left(\frac{-r'}{(4\pi)a_0}\right) \sin r's\, dr'$$

$$\int_0^{\infty} x^n e^{-\alpha x} \sin(xy)\, dx = n! \left(\frac{\alpha}{\alpha^2 + y^2}\right)^{n+1}$$

$$x \sum_{m=0}^{\frac{1}{2}n} (-1)^m \binom{n+1}{2m+1} \left(\frac{y}{\alpha}\right)^{2m+1}$$

Let $x = r$, $s = y$, $\alpha = 1/4\pi a_0$, $n = 2$

$$1/4\pi \int_0^{\infty} \frac{r^2}{(4\pi)^2 2\pi s} e^{-(r/4\pi a_0)} \sin rs\, dr = \frac{1}{(4\pi)^3 2\pi s}$$
$$(2!)\left(\frac{(1/4\pi a_0)}{(1/4\pi a_0)^2 + s^2}\right)^3$$

$$x \sum_{m=0}^{1} (-1)^m \binom{3}{2m+1} \left(\frac{s}{1/4\pi a_0}\right)^{2m+1}$$

Thus, the complete space-time Fourier transform of a Schrodinger wave equation is given as follows:

$$W(s, \Theta, \Phi, \omega) = \frac{1}{(4\pi)^3 2\pi s} (21) \left(\frac{(1/4\pi a_0)}{(1/4\pi a_0)^2 + s^2}\right)^3 {}_H \sum_{m=0}^{1} (-1)^m \binom{3}{2m+1} \left(\frac{s}{1/4\pi a_0}\right)^{2m+1}$$

$$\sum_{\upsilon=1}^{\infty} \frac{(-1)^{\upsilon-1}(\pi \sin\Phi)^{2(\upsilon-1)}}{\upsilon(\upsilon-1)!} \frac{\Gamma(\frac{1}{2})\Gamma(\upsilon+\frac{1}{2})}{2^{\upsilon+1}(\pi\cos\Theta)^{2\upsilon+1}} \frac{2\upsilon!}{\upsilon!} s^{-2\upsilon}$$

$$\sum_{\upsilon=1}^{\infty} \frac{(-1)^{\upsilon-1}(\pi \sin\Theta)^{2(\upsilon-1)}}{\upsilon(\upsilon-1)!} \frac{\Gamma(\frac{1}{2})\Gamma(\upsilon+\frac{1}{2})}{(\pi\cos\Theta)^{2\upsilon+1} 2^{\upsilon+1}} \frac{2\upsilon!}{\upsilon!} s^{-2\upsilon}$$

$$\frac{1}{4\pi} [\delta(\omega-\omega_0) + \delta(\omega+\omega_0)]$$

This transform has components $\frac{\omega_n}{c} = k$ which are not zero and are synchronous with waves traveling at the speed of light. Thus, a charge density function given by the Schrodinger wave equation must radiate in accordance with Maxwell's Equations.

Appendix IV

Derivation of the Orbital Energy Stored in the Magnetic Fields of Two Paired Electrons

Derivation of the Magnetic Field

Consider Figure 2; the magnetic field must satisfy the following relationships;

$$\nabla \cdot H = 0 \text{ in free space} \tag{IV.1}$$

$$n \times (\vec{H}_a - \vec{H}_b) = \vec{K} \tag{IV.2}$$

$$n \cdot (\vec{H}_a - \vec{H}_b) = 0 \tag{IV.3}$$

$$H = -\nabla \psi \tag{IV.4}$$

$$\vec{K} = \hat{i}_\phi \frac{3}{2} \frac{-e\hbar}{\mu r_n^3} \sin\theta \tag{IV.5}$$

$$H a_\theta - H b_\theta = \frac{3}{2} \frac{-e\hbar}{\mu r_n^3} \sin\theta \tag{IV.6}$$

To obtain H_θ ,the derivative of Ψ with respect to θ must be taken, and this suggests that the θ dependence of Ψ be taken as cos θ .The field is finite at the origin and is zero at infinity; so, solutions of Laplace's equation in spherical coordinates are selected because they are consistent with these conditions.

$$\Psi = C\left[\frac{r}{r_n}\right] \cos\theta \; ; \qquad r < r_n \tag{IV.7}$$

$$\Psi = A\left[\frac{r}{r_n}\right]^3 \cos\theta \; ; \qquad r > r_n \tag{IV.8}$$

The negative gradient of these potentials is

$$\vec{H} = \frac{-C}{r_n} (\hat{i}_r \cos\theta - \hat{i}_\theta \sin\theta) \quad \text{for } r < r_n \tag{IV.9}$$

$$\vec{H} = \frac{A}{r_n}\left[\frac{r}{r_n}\right]^3 (\hat{i}_r \, 2\cos\theta + \hat{i}_\theta \sin\theta) \text{ for } r > r_n \tag{IV.10}$$

The continuity conditions of Equations (IV.3), (IV.5), and (IV.6) and are applied to obtain the following relationships among the variables

$$\frac{-C}{r_n} = \frac{2A}{r_n} \tag{IV.11}$$

$$\frac{A}{r_n} - \frac{C}{r_n} = \frac{3}{2} \frac{-e\hbar}{\mu r_n^3} \tag{IV.12}$$

Solving the variables algebraically gives the magnetic fields of an

electron:

$$\vec{H} = \frac{e\hbar}{\mu r_n^3}\,(\hat{i}_r \cos\theta - \hat{i}_\theta \sin\theta) \quad \text{for } r < r_n \qquad \text{(IV.13)}$$

$$\vec{H} = \frac{e\hbar}{2\mu r^3}\,(\hat{i}_r\, 2\cos\theta - \hat{i}_\theta \sin\theta) \quad \text{for } r > r_n \qquad \text{(IV.14)}$$

Derivation of the Energy

The energy stored in the magnetic field of two electrons is

$$E_{mag} = 2\,\frac{1}{2}\,\mu_o \int_0^{2\pi}\int_0^{\pi}\int_0^{\infty} H^2 r^2 \sin\theta\, dr\, d\theta\, d\phi \qquad \text{(IV.15)}$$

$$E_{mag,total} = E_{mag,external} + E_{mag,internal} \qquad \text{(IV.16)}$$

$$E_{mag,internal} = \mu_o \int_0^{2\pi}\int_0^{\pi}\int_0^{r_1} \left[\frac{e\hbar}{\mu r_1^3}\right]^2 (\cos^2\theta + \sin^2\theta)\, r^2 \sin\theta\, dr\, d\theta\, d\phi \qquad \text{(IV.17)}$$

$$= \frac{4\pi\mu_o e^2\hbar^2}{3\mu^2 r_1^3} \qquad \text{(IV.18)}$$

$$E_{mag,external} = \mu_o \int_0^{2\pi}\int_0^{\pi}\int_{r_1}^{\infty} \left[\frac{e\hbar}{2\mu r^3}\right]^2 (4\cos^2\theta + \sin^2\theta)\, r^2 \sin\theta\, dr\, d\theta\, d\phi \qquad \text{(IV.19)}$$

$$= \frac{2\pi\mu_o e^2\hbar^2}{3\mu^2 r_1^3} \qquad \text{(IV.20)}$$

$$E_{mag,total} = \frac{4\pi\mu_o e^2\hbar^2}{3\mu^2 r_1^3} + \frac{2\pi\mu_o e^2\hbar^2}{3\mu^2 r_1^3} \qquad \text{(IV.21)}$$

$$E_{mag,total} = \frac{2\pi\mu_o e^2\hbar^2}{\mu^2 r_1^3} \qquad \text{(IV.22)}$$

Appendix V

The Hydrogen Molecule

It can be shown easily that the internuclear distance for the dihydrogen, H_2, is 0.748 Å. Consider two hydrogen atoms, A and B, approaching each other along the x-axis as shown in Figure 3. The radius of each Mills orbital is a_o. The electrostatic energy is

$$E_{interaction} = 2 \times \frac{1}{2} \epsilon_o \int \Delta \mathcal{E}^2 dv \qquad (V.1)$$

We define this energy as $E_{interaction}$. Recall that the electric field is zero for $r > a_o$. Until the orbitsphere penetrate the energy of interaction, $E_{interaction}$, is zero.

As the atoms move closer, the Mills orbitals begin to penetrate. When the penetration is small, as shown in Figure 4, $E_{interaction}$ decreases (is negative) because most of the electric field vectors from nucleus A in the overlap region are pointed in direct opposition to the B electric field vectors from nucleus B.

As the atoms move closer and the overlap increases, the $E_{interaction}$ will continue to decrease (become more negative). However, the decrease per unit volume will be smaller because a lower fraction of the A-vectors will be in direct opposition to the B-vectors. Figure 5 shows the two radial vectors and the net electric field vector (E_{AB}) for the point of intersection of the Mills orbitals.

We see that

$$E_A = E_B = \frac{K}{(a_o)^2} \qquad (V.2)$$

$$E_A^2 + E_A^2 = \frac{2K^2}{(a_o)^4} \qquad (V.3)$$

$$E_{xB} = E_{xA} \qquad (V.4)$$

$$E_{AB} = E_{yA} + E_{yB} = 2E_{yA} \qquad (V.5)$$

From the angle θ,

$$\sin\theta = \frac{y}{a_o} = \frac{E_{yA}}{E_A} = \frac{E_{yA}}{K/a_o} \qquad (V.6)$$

$$E_{yA} = \frac{yK}{(a_o)^3} \qquad (V.7)$$

$$E_{AB} = 2\frac{yK}{(a_o)^3} \qquad (V.8)$$

Therefore, $(E_{AB})^2$ will be less than $[(EA)^2 + (EB)^2]$ when

$$\frac{4y^2 K^2}{(a_o)^6} < \frac{2K^2}{(a_o)^4} \qquad (V.9)$$

$$y2 < \frac{(a_o)^2}{2} \quad \text{or} \quad y < \frac{a_o}{\sqrt{2}} \qquad (V.10)$$

Thus, for y = 0 to $y < a_o\sqrt{2}$ $E_{interaction}$ decreases. For $y > a_o/\sqrt{2}$ $E_{interaction}$ increases. And for $y = a_o/\sqrt{2}$, $E_{interaction}$ is a minimum. When $y = a_o/\sqrt{2}$

$$R_{AB} = xB = 2x \frac{a_o}{\sqrt{2}} = \sqrt{2}\, a_o = 0.748 \text{ Å} \qquad (V.11)$$

The experimental internuclear bond distance is 0.746 Å

Appendix VI

Calculation of the Resonant Energy Hole to Effect Shrinkage of the Radius of the Mills Orbital of the Deuterium Atom.

For the deuterium atom, the force relationship is given as follows:

$$\frac{\mu v^2}{r} = \frac{e^2}{4\pi\varepsilon_o r^2}$$

The boundary condition for nonradiative Mills orbitals derived in Appendix II, $2\pi r = n\lambda$, gives:

$$v = \frac{\hbar}{\mu r}.$$

Consider the case where the electron in the ground state losses kinetic energy, 1/2 mv^2, due to an inelastic collision for example, then the radius of the Mills orbital will shrink until the boundary condition is satisfied. The amount of energy which must be carried away (i.e., the magnitude of the energy hole absorbed) is calculated as follows:

Let r_1 = initial radius.

Let r_2 = final radius.

The force balance is:

$$\frac{\mu v^2}{r} = \frac{e^2}{4\pi\varepsilon_o r^2}$$

Vo is introduced as a perturbation of the velocity and the magnitude of the velocity change of the electron from the initial to final Mills orbital is calculated as follows:

$$\frac{\mu}{r_2}\left(\frac{\hbar}{\mu r_1} - Vo\right)^2 = \frac{e^2}{4\pi\varepsilon_o r_2^2}$$

$$\frac{\mu}{r_2}\left(\frac{\hbar^2}{\mu^2 r_1^2} - \frac{2\hbar}{\mu r_1}Vo + Vo^2\right) = \frac{e^2}{4\pi\varepsilon_o r_2^2}$$

$$Vo^2 - \frac{2\hbar}{\mu r_1}Vo + \frac{\hbar^2}{\mu^2 r_1^2} - \frac{e^2}{4\pi\varepsilon_o r_2} = 0$$

$$Vo = \frac{\frac{2\hbar}{\mu r_1} \pm \sqrt{4\frac{\hbar^2}{\mu^2 r_1^2} - 4\frac{\hbar^2}{\mu^2 r_1^2} + 4\frac{e^2}{\mu 4\pi\varepsilon_o r_2^2}}}{2}$$

$$Vo = \frac{\hbar}{\mu r_1} \pm \sqrt{\frac{e^2}{\mu 4\pi\varepsilon_o r_2}}$$

$$\frac{e^2}{4\pi\varepsilon_o} = \frac{\hbar^2}{\mu a_0}$$

$$V_o = \frac{\hbar}{\mu r_1} \pm \sqrt{\frac{\hbar^2}{\mu^2 a_0 r_2}}$$

For the ground state, the radius of the Mills orbital was determined in the One Electron Atom Section to be a_o. Thus, the boundary condition is given as follows:

$$2\pi a_o = \lambda$$

From the boundary condition, $2\pi r = n\lambda$, with $r < a_o$, the radius of any shrunken state is an integer fraction of the radius of the ground state. Thus, for the first shrunken state

$$r_2 = \frac{a_0}{2} \text{ , and in general}$$

$$r_2 = \frac{a_0}{n}$$

Substituting $r_1 = a_o$ and $r_2 = \frac{a_0}{n}$ into the relationship for Vo gives

$$V_o = \frac{\hbar}{\mu a_0} \pm \sqrt{\frac{\hbar^2 n}{\mu^2 a_0^2}}$$

$$V_o = \frac{\hbar}{\mu a_0} \pm \sqrt{n}\frac{\hbar}{\mu a_0}$$

$n=2,3,4.....$

The angular velocity of the electron in ground state is $\frac{\hbar}{\mu a_0}$ and the angular velocity in the first shrunken state is $\frac{2\hbar}{\mu a_0}$.

Consider the velocity of the centripetal force equation:

$$\frac{\mu}{r_2}\left(\frac{\hbar}{\mu r_1} \cdot V_o\right)^2 = F_c$$

and the relationship resulting from the perturbation:

$$V_o = \frac{\hbar}{\mu a_0} \pm \sqrt{n}\frac{\hbar}{\mu a_0} \qquad n=2,3,4.....$$

In order to satisfy the boundary conditions, the first term of V_0, $\frac{\hbar}{\mu a_0}$.

must be negative so that it adds to the initial velocity $\frac{\hbar}{\mu a_0}$ to give the final velocity $\frac{2\hbar}{\mu a_0}$, and the kinetic energy due to the velocity component $\sqrt{n}\frac{\hbar}{\mu a_0}$ must be removed to effect the shrinkage transition.

The magnitude of the energy hole which arises from this term is calculated as follows:

$$E = \frac{1}{2}\mu v^2 = \frac{1}{2}\mu(\sqrt{n}\frac{\hbar}{\mu a_0})^2$$

$$E = \frac{1}{2}\mu n \frac{\hbar^2}{\mu^2 a_0^2}$$

$n=2,3,4.....$

Thus, the absorbed energy hole which effects shrinkage is quantized. For the shrinkage transition $n = 1$ to $n = 2$, the resonant energy loss to shrink a Mills orbital by $a_0\left(\frac{1}{n_1} - \frac{1}{n_2}\right)$ where n_1 is the quantum number of the initial orbital and n_2 is the quantum number of the final orbital is given as follows:

$$E = \frac{1}{2} n \frac{\hbar^2}{\mu a_0^2};\ n=2$$

$$E = \frac{\hbar^2}{\mu a_0^2} = \frac{(1.05459 \times 10^{-34})^2}{(9.10953 \times 10^{-31})(5.29177 \times 10^{-11})^2}$$

$$E = 4.3598285 \times 10^{-18} J = 27.211682 eV$$

Thus, shrinkage requires the electron to lose a resonance energy of $\frac{n}{2}$ 27.21 eV where $n = 2, 3, 4,.....$.

Notice that absorption of an energy hole reduces the radius; whereas, absorption of energy as a photon increases the radius. The former increases the coulombic force by the multiple of n; the latter decreases the coulombic force by the multiple of $\frac{1}{n}$ where n is the integer of the transition; thus, the force balance, and the boundary conditions for nonradiation are satisfied.

Appendix VII

Detailed Description of Figure 1. Mills Orbitals

Mills orbitals are obtained by adding a constant sphere which is normalized to a spherical harmonic which is normalized. This function is the charge density on the surface of the spherical delta function that comprises the Mills orbital. The former can be consider the base charge density whose current gives rise to magnetic spin, and the latter can be considered a charge density function which creates modulation of the former and whose traveling wave of current gives rise to orbital angular momentum. The total charge of the Mills orbital for an electron is e and the total mass is μ.

The application entitled ENERGY/ MATTER CONVERSION METHODS AND STRUCTURES filed April 21, 1989 is herein incorporated by reference.

These and further methods and embodiments arising from substitution and modifications made by one of ordinary skill in the art are considered within the scope of the present invention. For instance, in the case of energy release through fusion according to the present invention, the fusion material may include more than one element or molecule, where corresponding energy holes are provided for each fusion element. Therefore, the present invention is not limited except by the claims which follow.

CLAIMS

What is claimed is:

1. A method of releasing energy, comprising the steps of:

selecting a first element of matter having a nucleus and at least one electron orbital;

selecting a second element of matter having a nucleus and, at least one electron orbital;

determining the resonance shrinkage energy levels of the electron orbitals of said first and second elements of matter;

providing two energy holes substantially equal to each of the resonance shrinkage energy levels of said first and second elements of matter;

juxtaposing said first and second elements of matter and said energy holes, wherein;

fusion of said first and second elements of matter is produced when the energy of said first and second elements of matter is removed by said energy holes from said electron orbitals to permit forces from each nucleus of said first and second element of matter to be attractive to form a common nucleus, providing the release of energy.

2. The method of claim 1, wherein:

said first and second elements of matter comprise the same element of matter.

3. The method of claim 1, wherein said step of providing an energy hole for each fusionable element comprises the step of selecting a third element of matter having an ionization energy substantially equal to the resonance shrinkage energy of said first and second elements of matter.

4. The method of claim 3, further comprising the step of transferring energy between said juxtaposed first and second elements of matter and external energy apparatus, said energy hole to control the rate of fusion according to the relative equivalence of said energy hole and transferred energy to the energy levels of said first and second elements of matter.

5. The method of claim 1, wherein the step of providing an energy hole comprises the steps of:

selecting a plurality of elements of matter, each having an ionization energy, wherein each of said plurality of elements of matter are selected to produce a difference in ionization energies substantially

equal to the energy resonance shrinkage energy of said first element of matter.

6. The method of claim 1, wherein said first and second elements of matter comprise different elements of matter.

7. The method of claim 6, wherein said step of providing an energy hole for each of said first and second elements comprises the step of:

selecting a third and fourth element of matter each having an ionization energy substantially equal to the resonance shrinkage energy of the respective first and second elements.

8. The method of claim 6, wherein said step of providing an energy hole for each of said first and second elements comprising the step of:

selecting a plurality of elements providing a difference in ionization energies substantially equal to at least one of the resonance shrinkage energy of said first and second elements.

9. The method of claim 8, wherein the step of providing an energy hole includes the step of:

selecting an additional element providing an ionization energy equal to the other resonance shrinkage energy of said first and second element.

10. The method of claim 5, further comprises the step of transferring energy between said juxtaposed first and second elements of matter and external energy apparatus, said energy hole to control the rate of fusion according to the relative equivalence of said energy hole and transferred energy to the resonance shrinkage energy levels of said first and second elements of matter.

11. The method of claim 10, wherein the transfer of energy is provided by one of an externally applied electric, magnetic field, or heat transfer and acoustic energy.

12. The method of claim 1, wherein the step of determining the resonance shrinkage energy comprises the step of calculating the said energy of the electron orbitals.

13. The method of claim 12, wherein the step of calculating comprises the steps of:

equating the sum of the magnetic and coulombic forces with the centripetal force;

introducing an energy hole into the centripetal force as a velocity deficit; and

determining the energy hole by solving for the energy in the velocity deficit where the boundary conditions of Mills orbital, $2\pi r = n\lambda$ is observed.

14. The method of claim 1, wherein:

said first and second elements of matter have an atomic number of 26 or less.

15. The method of claim 1, wherein the step of providing an energy hole comprises:

providing a catalytic system.

16. The method of claim 15, wherein the step of providing a catalytic system comprises:

providing an electrochemical reactant comprising at least one of a cation and an anion.

17. Apparatus for providing the release of energy, comprising:

means for providing a first and second element of matter in a selected volume, each of said first and second elements having a nucleus and at least one electron at an orbital having a respective resonance shrinkage energy level; and

a substance introduced into said selected volume for providing an energy hole in juxtaposition with said first and second elements of matter, said energy hole having a magnitude substantially equal to said resonance shrinkage energy, wherein:

fusion of said first and second elements of matter is produced when the orbitals of said first and second elements of matter are reduced due to removal of orbital energy by said energy hole permitting forces from each nucleus of said first and second elements of matter to form a common nucleus, providing the release of energy.

18. The apparatus of claim 17, wherein said substance comprises at least a third element of matter having an ionization energy substantially equal to the resonance shrinkage energy of each of said first and second elements of matter.

19. The apparatus of claim 18, wherein said substance further comprises at least an additional element of matter having an ionization energy, which in combination with the ionization energy of said third element produce said energy hole substantially equal to the resonance shrinkage energy of at least one of said first and second elements of

matter.

20. The apparatus of claim 18, wherein:

said first and second elements of matter are the same elements.

21. The apparatus of claim 20, wherein:

said first and second elements of matter have an atomic number of 26 or less.

22. The apparatus of claim 18, wherein:

said first and second elements of matter comprises one of ^{2}H, ^{3}H, ^{6}Li; and

said third element comprises Ti^{2+}.

23. The apparatus of claim 22, wherein said first and second elements of matter comprise deuterium and said third element comprises one of:

single-ion capable of producing energy holes for shrinking deuterium atoms. The number following the atomic symbol (n) is the nth ionization energy of the atom. That is for example, Ti^{2+} + 27.49 eV = Ti^{3+} + e^{-}.

Catalytic Ion	n	nth ionization energy
Al^{2+}	3	28.45
Ar^{1+}	2	27.63
Ti^{2+}	3	27.49
As^{2+}	3	28.35
Rb^{1+}	2	27.28
Mo^{2+}	3	27.16
Ru^{2+}	3	28.47
In^{2+}	3	28.03
Te^{2+}	3	27.96

n = 16 (resonance shrinkage energy is given by $\frac{n}{2}$ 27.21; with n = 16, the resonance shrinkage energy is 217.68)

Catalytic Ion	n	nth ionization energy
Be^{3+}	4	217.71
$P5+$	6	220.43

24. The apparatus of claim 20, wherein:

said first and second elements of matter comprises ^{2}H and ^{3}H; and

said third and said additional element comprise Pd^{2+} and Li^{+}.

25. The apparatus of claim 20, wherein said first and second elements of matter comprise deuterium and said third and fourth elements of

matter comprise on of the following two-ion couples:

Two-ion couples capable of producing energy holes for shrinking deuterium atoms. The number in the column following the ion, (n), is the nth ionization energy of the atom. That is for example, Pd^{2+} + 32.93 eV = Pd^{3+} + e^- and $Li^+ + e^- = Li$ + 5.39 eV.

Atom Oxidized	n	nth Ionization Energy (eV)	Atom Reduced	n	nth Ionization Energy (eV)	Energy Hole (eV)
Ne 1 +	2	40.96	H 1 +	1	13.60	27.36
Ar 2 +	3	40.74	H 1 +	1	13.60	27.14
Sn 3 +	4	40.73	H 1 +	1	13.60	27.14
Pm 3 +	4	41.10	H 1 +	1	13.60	27.50
Sm 3 +	4	41.40	H 1 +	1	13.60	27.80
Dy 3 +	4	41.50	H 1 +	1	13.60	27.90
Kr 3 +	4	52.50	He 1 +	1	24.59	27.91
Rb 3 +	4	52.60	He 1 +	1	24.59	28.01
K 4 +	5	82.66	He 2 +	2	54.42	28.24
Zn 4 +	5	82.60	He 2 +	2	54.42	28.18
Se 5 +	6	81.70	He 2 +	2	54.42	27.28
He 1 +	2	54.42	Rb 2 +	2	27.28	27.14
Zr 4 +	5	81.50	He 2 +	2	54.42	27.08
He 1 +	2	54.42	Mo 3 +	3	27.16	27.26
Si 2 +	3	33.49	Li 1 +	1	5.39	28.10
Mn 2 +	3	33.67	Li 1 +	1	5.39	28.27
Co 2 +	3	33.50	Li 1 +	1	5.39	28.11
Pd 2 +	3	32.93	Li 1 +	1	5.39	27.54
I 2 +	3	33.00	Li 1 +	1	5.39	27.61
Hf 3 +	4	33.33	Li 1 +	1	5.39	27.94
Li 1 +	2	75.64	C 3 +	3	47.89	27.75
Li 1 +	2	75.64	N 3 +	3	47.45	28.19
Li 1 +	2	75.64	Na 2 +	2	47.29	28.35
Li 1 +	2	75.64	S 4 +	4	47.30	28.34
Cu 5 +	6	103.00	Li 2 +	2	75.64	27.36
Li 1 +	2	75.64	Br 4 +	4	47.30	28.34
Br 6 +	7	103.00	Li 2 +	2	75.64	27.36

	V 6 +	7	150.17	Li 3 +	3	122.45	27.72
	Li 2 +	3	122.45	Mn 6 +	6	95.00	27.45
	Cu 2 +	3	36.83	Be 1 +	1	9.32	27.51
	Kr 2 +	3	36.95	Be 1 +	1	9.32	27.63
5	Cd 2 +	3	37.48	Be 1 +	1	9.32	28.16
	Te 3 +	4	37.41	Be 1 +	1	9.32	28.09
	Ce 3 +	4	36.76	Be 1 +	1	9.32	27.44
	K 2 +	3	45.72	Be 2 +	2	18.21	27.51
	V 3 +	4	46.71	Be 2 +	2	18.21	28.50
10	Ge 3 +	4	45.71	Be 2 +	2	18.21	27.50
	Mo 3 +	4	46.40	Be 2 +	2	18.21	28.19
	Bi 3 +	4	45.30	Be 2 +	2	18.21	27.09
	Be 2 +	3	153.89	Ne 5 +	5	126.21	27.68
	Be 2 +	3	153.89	Kr 8 +	8	126.00	27.89
15	Be 2 +	3	153.89	Mo 7 +	7	126.80	27.09
	Be 3 +	4	217.71	Al 6 +	6	190.47	27.24
	Br 2 +	3	36.00	B 1 +	1	8.30	27.70
	Ce 3 +	4	36.76	B 1 +	1	8.30	28.46
	Cl 3 +	4	53.46	B 2 +	2	25.15	28.31
20	Kr 3 +	4	52.50	B 2 +	2	25.15	27.35
	Rb 3 +	4	52.60	B 2 +	2	25.15	27.45
	B 2 +	3	37.93	P 1 +	1	10.49	27.44
	P 4 +	5	65.02	B 3 +	3	37.93	27.09
	B 2 +	3	37.93	S 1 +	1	10.36	27.57
25	V 4 +	5	65.23	B 3 +	3	37.93	27.30
	B 2 +	3	37.93	As 1 +	1	9.81	28.12
	B 2 +	3	37.93	Se 1 +	1	9.75	28.18
	B 2 +	3	37.93	I 1 +	1	10.45	27.48
	B 2 +	3	37.93	Ba 2 +	2	10.00	27.93
30	B 2 +	3	37.93	Ce 2 +	2	10.85	27.08
	B 2 +	3	37.93	Pr 2 +	2	10.55	27.38
	B 2 +	3	37.93	Nd 2 +	2	10.73	27.20
	B 2 +	3	37.93	Pm 2 +	2	10.90	27.03
	B 2 +	3	37.93	Hg 1 +	1	10.44	27.49
35	B 2 +	3	37.93	Rn 1 +	1	10.75	27.18
	B 2 +	3	37.93	Ra 2 +	2	10.15	27.78

Cl 2 +	3	39.61	C 1 +	1	11.26	28.35
Zn 2 +	3	39.72	C 1 +	1	11.26	28.46
Nb 3 +	4	38.30	C 1 +	1	11.26	27.04
Pr 3 +	4	38.98	C 1 +	1	11.26	27.72
Kr 3 +	4	52.50	C 2 +	2	24.38	28.12
Rb 3 +	4	52.60	C 2 +	2	24.38	28.22
C 2 +	3	47.89	P 2 +	2	19.73	28.16
Ar 4 +	5	75.02	C 3 +	3	47.89	27.13
Fe 4 +	5	75.00	C 3 +	3	47.89	27.11
Ni 4 +	5	75.50	C 3 +	3	47.89	27.61
C 2 +	3	47.89	Cu 2 +	2	20.29	27.60
C 2 +	3	47.89	Ga 2 +	2	20.51	27.38
C 2 +	3	47.89	Y 3 +	3	20.52	27.37
C 2 +	3	47.89	Pd 2 +	2	19.43	28.46
C 2 +	3	47.89	Ce 3 +	3	20.20	27.69
C 2 +	3	47.89	Gd 3 +	3	20.63	27.26
C 2 +	3	47.89	Au 2 +	2	20.50	27.39
C 2 +	3	47.89	Tl 2 +	2	20.43	27.46
Sc 4 +	5	91.66	C 4 +	4	64.49	27.17
C 3 +	4	64.49	Cu 3 +	3	36.83	27.66
C 3 +	4	64.49	Br 3 +	3	36.00	28.49
C 3 +	4	64.49	Kr 3 +	3	36.95	27.54
C 3 +	4	64.49	Cd 3 +	3	37.48	27.01
C 3 +	4	64.49	Te 4 +	4	37.41	27.08
C 3 +	4	64.49	Ce 4 +	4	36.76	27.73
Se 3 +	4	42.94	N 1 +	1	14.53	28.41
Eu 3 +	4	42.60	N 1 +	1	14.53	28.07
Ho 3 +	4	42.50	N 1 +	1	14.53	27.97
Er 3 +	4	42.60	N 1 +	1	14.53	28.07
Tm 3 +	4	42.70	N 1 +	1	14.53	28.17
Pb 3 +	4	42.32	N 1 +	1	14.53	27.79
Sr 3 +	4	57.00	N 2 +	2	29.60	27.40
N 2 +	3	47.45	P 2 +	2	19.73	27.72
Ar 4 +	5	75.02	N 3 +	3	47.45	27.57
Fe 4 +	5	75.00	N 3 +	3	47.45	27.55
Ni 4 +	5	75.50	N 3 +	3	47.45	28.05

N 2+	3	47.45	
N 2+	3	47.45	
N 2+	3	47.45	
N 2+	3	47.45	
N 2+	3	47.45	
N 2+	3	47.45	
N 3+	4	77.47	
N 3+	4	77.47	
N 3+	4	77.47	
Ne 4+	5	126.21	
Fe 6+	7	125.00	
Kr 7+	8	126.00	
Nb 6+	7	125.00	
N 4+	5	97.89	
Ne 1+	2	40.96	
Ar 2+	3	40.74	
Sn 3+	4	40.73	
Pm 3+	4	41.10	
Sm 3+	4	41.40	
Dy 3+	4	41.50	
F 2+	3	62.71	
Ne 2+	3	63.45	
O 1+	2	35.12	
O 1+	2	35.12	
O 1+	2	35.12	
O 1+	2	35.12	
O 1+	2	35.12	
O 1+	2	35.12	
O 1+	2	35.12	
O 1+	2	35.12	
O 1+	2	35.12	
O 1+	2	35.12	
O 1+	2	35.12	
O 1+	2	35.12	
Cu 2+	2	20.29	27.16
Pd 2+	2	19.43	28.02
I 2+	2	19.13	28.32
La 3+	3	19.18	28.27
Ce 3+	3	20.20	27.25
Tl 2+	2	20.43	27.02
Cr 4+	4	49.10	28.37
As 4+	4	50.13	27.34
La 4+	4	49.95	27.52
N 5+	5	97.89	28.32
N 5+	5	97.89	27.11
N 5+	5	97.89	28.11
N 5+	5	97.89	27.11
Te 6+	6	70.70	27.19
O 1+	1	13.62	27.34
O 1+	1	13.62	27.12
O 1+	1	13.62	27.12
O 1+	1	13.62	27.48
O 1+	1	13.62	27.78
O 1+	1	13.62	27.88
O 2+	2	35.12	27.59
O 2+	2	35.12	28.33
Mg 1+	1	7.65	27.47
Ti 1+	1	6.82	28.30
V 1+	1	6.74	28.38
Cr 1+	1	6.77	28.35
Mn 1+	1	7.43	27.68
Fe 1+	1	7.87	27.25
Co 1+	1	7.86	27.26
Ni 1+	1	7.64	27.48
Cu 1+	1	7.73	27.39
Ge 1+	1	7.90	27.22
Zr 1+	1	6.84	28.28
Nb 1+	1	6.88	28.24
Mo 1+	1	7.10	28.02
Tc 1+	1	7.28	27.84

O 1 +	2	35.12		Ru 1 +	1	7.37	27.75
O 1 +	2	35.12		Rh 1 +	1	7.46	27.66
O 1 +	2	35.12		Ag 1 +	1	7.58	27.54
O 1 +	2	35.12		Sn 1 +	1	7.34	27.77
O 1 +	2	35.12		Ta 1 +	1	7.89	27.23
O 1 +	2	35.12		W 1 +	1	7.98	27.14
O 1 +	2	35.12		Re 1 +	1	7.88	27.24
O 1 +	2	35.12		Pb 1 +	1	7.42	27.70
O 1 +	2	35.12		Bi 1 +	1	7.29	27.83
O 2 +	3	54.93		Ar 2 +	2	27.63	27.30
K 4 +	5	82.66		O 3 +	3	54.93	27.73
O 2 +	3	54.93		Ti 3 +	3	27.49	27.44
Zn 4 +	5	82.60		O 3 +	3	54.93	27.67
O 2 +	3	54.93		Rb 2 +	2	27.28	27.65
O 2 +	3	54.93		Mo 3 +	3	27.16	27.77
O 3 +	4	77.41		Cr 4 +	4	49.10	28.31
O 3 +	4	77.41		As 4 +	4	50.13	27.28
O 3 +	4	77.41		La 4 +	4	49.95	27.46
Mg 4 +	5	141.26		O 5 +	5	113.90	27.36
O 5 +	6	138.12		Sc 6 +	6	111.10	27.02
Cu 7 +	8	166.00		O 6 +	6	138.12	27.88
O 5 +	6	138.12		Kr 7 +	7	111.00	27.12
Si 3 +	4	45.14		F 1 +	1	17.42	27.72
K 2 +	3	45.72		F 1 +	1	17.42	28.30
Ge 3 +	4	45.71		F 1 +	1	17.42	28.29
Lu 3 +	4	45.19		F 1 +	1	17.42	27.77
Bi 3 +	4	45.30		F 1 +	1	17.42	27.88
F 2 +	3	62.71		F 2 +	2	34.97	27.74
Ne 2 +	3	63.45		F 2 +	2	34.97	28.48
F 1 +	2	34.97		Mg 1 +	1	7.65	27.32
F 1 +	2	34.97		Sc 1 +	1	6.54	28.43
F 1 +	2	34.97		Ti 1 +	1	6.82	28.15
F 1 +	2	34.97		V 1 +	1	6.74	28.23
F 1 +	2	34.97		Cr 1 +	1	6.77	28.20
F 1 +	2	34.97		Mn 1 +	1	7.43	27.54
F 1 +	2	34.97		Fe 1 +	1	7.87	27.10

F 1 +	2	34.97	Co 1 +	1	7.86	27.11
F 1 +	2	34.97	Ni 1 +	1	7.64	27.34
F 1 +	2	34.97	Cu 1 +	1	7.73	27.24
F 1 +	2	34.97	Ge 1 +	1	7.90	27.07
F 1 +	2	34.97	Zr 1 +	1	6.84	28.13
F 1 +	2	34.97	Nb 1 +	1	6.88	28.09
F 1 +	2	34.97	Mo 1 +	1	7.10	27.87
F 1 +	2	34.97	Tc 1 +	1	7.28	27.69
F 1 +	2	34.97	Ru 1 +	1	7.37	27.60
F 1 +	2	34.97	Rh 1 +	1	7.46	27.51
F 1 +	2	34.97	Ag 1 +	1	7.58	27.39
F 1 +	2	34.97	Sn 1	1	7.34	27.63
F 1 +	2	34.97	Hf 1 +	1	6.60	28.37
F 1 +	2	34.97	Ta 1 +	1	7.89	27.08
F 1 +	2	34.97	Re 1 +	1	7.88	27.09
F 1 +	2	34.97	Pb 1 +	1	7.42	27.55
F 1 +	2	34.97	Bi 1 +	1	7.29	27.68
F 2 +	3	62.71	F 2 +	2	34.97	27.74
F 2 +	3	62.71	S 3 +	3	34.83	27.88
Ar 5 +	6	91.01	F 3 +	3	62.71	28.30
Cr 5 +	6	90.56	F 3 +	3	62.71	27.85
F 2 +	3	62.71	Ni 3 +	3	35.17	27.54
F 2 +	3	62.71	Ge 3 +	3	34.22	28.49
Sr 5 +	6	90.80	F 3 +	3	62.71	28.09
F 2 +	3	62.71	Zr 4 +	4	34.34	28.37
F 2 +	3	62.71	Ag 3 +	3	34.83	27.88
F 4 +	5	114.24	F 4 +	4	87.14	27.10
Cl 6 +	7	114.19	F 4 +	4	87.14	27.06
F 3 +	4	87.14	Ar 4 +	4	59.81	27.33
F 3 +	4	87.14	Zn 4 +	4	59.40	27.74
F 3 +	4	87.14	Br 5 +	5	59.70	27.44
F 3 +	4	87.14	Te 5 +	5	58.75	28.39
F 4 +	5	114.24	F 4 +	4	87.14	27.10
Mg 4 +	5	141.26	F 5 +	5	114.24	27.02
F 6 +	7	185.18	F 6 +	6	157.16	28.02
Cr 7 +	8	184.70	F 6 +	6	157.16	27.54

F 5 +	6	157.16		Co 7 +	7	129.00	28.16
F 5 +	6	157.16		Y 8 +	8	129.00	28.16
F 6 +	7	185.18		F 6 +	6	157.16	28.02
F 6 +	7	185.18		Ne 6 +	6	157.93	27.25
F 6 +	7	185.18		Co 8 +	8	157.00	28.18
Cr 3 +	4	49.10		Ne 1 +	1	21.56	27.54
La 3 +	4	49.95		Ne 1 +	1	21.56	28.39
Ne 1 +	2	40.96		Cl 1 +	1	12.97	28.00
Ne 1 +	2	40.96		Sc 2 +	2	12.80	28.16
Ne 1 +	2	40.96		Ti 2 +	2	13.58	27.38
Cr 4 +	5	69.30		Ne 2 +	2	40.96	28.34
Se 4 +	5	68.30		Ne 2 +	2	40.96	27.34
Ne 1 +	2	40.96		Zr 2 +	2	13.13	27.83
Mo 5 +	6	68.00		Ne 2 +	2	40.96	27.04
Ne 1 +	2	40.96		Lu 2 +	2	13.90	27.06
Pb 4 +	5	68.80		Ne 2 +	2	40.96	27.84
Ar 5 +	6	91.01		Ne 3 +	3	63.45	27.56
Sc 4 +	5	91.66		Ne 3 +	3	63.45	28.21
Cr 5 +	6	90.56		Ne 3 +	3	63.45	27.11
Ne 2 +	3	63.45		Ni 3 +	3	35.17	28.28
Ne 2 +	3	63.45		Br 3 +	3	36.00	27.45
Sr 5 +	6	90.80		Ne 3 +	3	63.45	27.35
Ar 6 +	7	124.32		Ne 4 +	4	97.11	27.21
Ne 3 +	4	97.11		Cr 5 +	5	69.30	27.81
Fe 6 +	7	125.00		Ne 4 +	4	97.11	27.89
Nb 6 +	7	125.00		Ne 4 +	4	97.11	27.89
Ne 3 +	4	97.11		Pb 5 +	5	68.80	28.31
Ne 4 +	5	126.21		Na 4 +	4	98.91	27.30
Al 4 +	5	153.71		Ne 5 +	5	126.21	27.50
Ne 4 +	5	126.21		Fe 6 +	6	99.00	27.21
Ne 4 +	5	126.21		Rb 7 +	7	99.20	27.01
Si 2 +	3	33.49		Na 1 +	1	5.14	28.35
Co 2 +	3	33.50		Na 1 +	1	5.14	28.36
Pd 2 +	3	32.93		Na 1 +	1	5.14	27.79
I 2 +	3	33.00		Na 1 +	1	5.14	27.86
Hf 3 +	4	33.33		Na 1 +	1	5.14	28.19

Na 1 +	2	47.29		Al 2 +	2	18.83	28.46
Na 1 +	2	47.29		P 2 +	2	19.73	27.56
Ar 4 +	5	75.02		Na 2 +	2	47.29	27.73
Fe 4 +	5	75.00		Na 2 +	2	47.29	27.71
Ni 4 +	5	75.50		Na 2 +	2	47.29	28.21
Na 1 +	2	47.29		Pd 2 +	2	19.43	27.86
Na 1 +	2	47.29		In 2 +	2	18.87	28.42
Na 1 +	2	47.29		I 2 +	2	19.13	28.15
Na 1 +	2	47.29		La 3 +	3	19.18	28.11
Na 1 +	2	47.29		Ce 3 +	3	20.20	27.09
Na 3 +	4	98.91		Na 3 +	3	71.64	27.27
K 5 +	6	100.00		Na 3 +	3	71.64	28.36
Na 2 +	3	71.64		Ti 4 +	4	43.27	28.37
Ti 4 +	5	99.22		Na 3 +	3	71.64	27.58
Fe 5 +	6	99.00		Na 3 +	3	71.64	27.36
Rb 6 +	7	99.20		Na 3 +	3	71.64	27.56
Na 2 +	3	71.64		Sr 3 +	3	43.60	28.04
Na 2 +	3	71.64		Sb 4 +	4	44.20	27.44
Na 2 +	3	71.64		Gd 4 +	4	44.00	27.64
Na 2 +	3	71.64		Yb 4 +	4	43.70	27.94
Na 3 +	4	98.91		Na 3 +	3	71.64	27.27
Kr 7 +	8	126.00		Na 4 +	4	98.91	27.09
Na 3 +	4	98.91		Rb 5 +	5	71.00	27.91
Na 3 +	4	98.91		Sr 5 +	5	71.60	27.31
Mo 6 +	7	126.80		Na 4 +	4	98.91	27.89
Na 3 +	4	98.91		Te 6 +	6	70.70	28.21
Si 4 +	5	166.77		Na 5 +	5	138.39	28.38
Na 4 +	5	138.39		Sc 6 +	6	111.10	27.29
Cu 7 +	8	166.00		Na 5 +	5	138.39	27.61
Na 4 +	5	138.39		Kr 7 +	7	111.00	27.39
S 2 +	3	34.83		Mg 1 +	1	7.65	27.18
Ni 2 +	3	35.17		Mg 1 +	1	7.65	27.52
Br 2 +	3	36.00		Mg 1 +	1	7.65	28.35
Ag 2 +	3	34.83		Mg 1 +	1	7.65	27.18
Ti 3 +	4	43.27		Mg 2 +	2	15.03	28.23
Se 3 +	4	42.94		Mg 2 +	2	15.03	27.91

Eu 3 +	4	42.60	
Ho 3 +	4	42.50	
Er 3 +	4	42.60	
Tm 3 +	4	42.70	
Pb 3 +	4	42.32	
Ni 5 +	6	108.00	
Zn 5 +	6	108.00	
Mg 2 +	3	80.14	
Mg 2 +	3	80.14	
Sb 5 +	6	108.00	
Mg 3 +	4	109.24	
Mg 3 +	4	109.24	
Te 6 +	7	137.00	
Mg 4 +	5	141.26	
Ti 7 +	8	168.50	
Mg 5 +	6	186.50	
Mg 6 +	7	224.94	
Si 2 +	3	33.49	
Mn 2 +	3	33.67	
Co 2 +	3	33.50	
Ge 2 +	3	34.22	
Zr 3 +	4	34.34	
I 2 +	3	33.00	
Hf 3 +	4	33.33	
Hg 2 +	3	34.20	
S 3 +	4	47.30	
V 3 +	4	46.71	
Br 3 +	4	47.30	
Mo 3 +	4	46.40	
Sb 4 +	5	56.00	
Bi 4 +	5	56.00	
Ca 7 +	8	147.24	
Al 3 +	4	119.99	
Al 4 +	5	153.71	
Al 5 +	6	190.47	
Ni 2 +	3	35.17	
Mg 2 +	2	15.03	27.56
Mg 2 +	2	15.03	27.47
Mg 2 +	2	15.03	27.56
Mg 2 +	2	15.03	27.67
Mg 2 +	2	15.03	27.28
Mg 3 +	3	80.14	27.86
Mg 3 +	3	80.14	27.86
Kr 4 +	4	52.50	27.64
Rb 4 +	4	52.60	27.54
Mg 3 +	3	80.14	27.86
Se 6 +	6	81.70	27.54
Zr 5 +	5	81.50	27.74
Mg 4 +	4	109.24	27.76
Cl 7 +	7	114.19	27.07
Mg 5 +	5	141.26	27.24
Sc 8 +	8	158.70	27.80
Mn 8 +	8	196.46	28.48
Al 1 +	1	5.99	27.51
Al 1 +	1	5.99	27.68
Al 1 +	1	5.99	27.51
Al 1 +	1	5.99	28.23
Al 1 +	1	5.99	28.35
Al 1 +	1	5.99	27.01
Al 1 +	1	5.99	27.34
Al 1 +	1	5.99	28.21
Al 2 +	2	18.83	28.47
Al 2 +	2	18.83	27.88
Al 2 +	2	18.83	28.47
Al 2 +	2	18.83	27.57
Al 3 +	3	28.45	27.55
Al 3 +	3	28.45	27.55
Al 4 +	4	119.99	27.25
Sc 5 +	5	91.66	28.33
Kr 8 +	8	126.00	27.71
Ni 8 +	8	162.00	28.47
Si 1 +	1	8.15	27.02

Br 2 +	3	36.00	Si 1 +	1	8.15	27.85
Sr 2 +	3	43.60	Si 2 +	2	16.34	27.25
Sb 3 +	4	44.20	Si 2 +	2	16.34	27.86
Gd 3 +	4	44.00	Si 2 +	2	16.34	27.66
Yb 3 +	4	43.70	Si 2 +	2	16.34	27.36
K 3 +	4	60.91	Si 3 +	3	33.49	27.42
Si 2 +	3	33.49	Ca 1 +	1	6.11	27.38
Si 2 +	3	33.49	Ga 1 +	1	6.00	27.49
Si 2 +	3	33.49	Sr 1 +	1	5.70	27.80
Si 2 +	3	33.49	Y 1 +	1	6.38	27.11
Y 3 +	3	61.80	Si 3 +	3	33.49	28.31
Mo 4 +	5	61.20	Si 3 +	3	33.49	27.71
Si 2 +	3	33.49	In 1 +	1	5.79	27.71
Si 2 +	3	33.49	Ba 1 +	1	5.21	28.28
Si 2 +	3	33.49	La 1 +	1	5.58	27.92
Si 2 +	3	33.49	Ce 1 +	1	5.47	28.02
Si 2 +	3	33.49	Pr 1 +	1	5.42	28.07
Si 2 +	3	33.49	Nd 1 +	1	5.49	28.00
Si 2 +	3	33.49	Pm 1 +	1	5.55	27.94
Si 2 +	3	33.49	Sm 1 +	1	5.63	27.86
Si 2 +	3	33.49	Eu 1 +	1	5.67	27.83
Si 2 +	3	33.49	Gd 1 +	1	6.14	27.35
Si 2 +	3	33.49	Tb 1 +	1	5.85	27.64
Si 2 +	3	33.49	Dy 1 +	1	5.93	27.57
Si 2 +	3	33.49	Ho 1 +	1	6.02	27.47
Si 2 +	3	33.49	Er 1 +	1	6.10	27.39
Si 2 +	3	33.49	Tm 1 +	1	6.18	27.31
Si 2 +	3	33.49	Yb 1 +	1	6.25	27.24
Si 2 +	3	33.49	Lu 1 +	1	5.43	28.07
Si 2 +	3	33.49	Tl 1 +	1	6.11	27.38
Si 2 +	3	33.49	Ra 1 +	1	5.28	28.21
Si 2 +	3	33.49	Ac 1 +	1	5.20	28.29
Si 2 +	3	33.49	Th 1 +	1	6.10	27.39
Si 2 +	3	33.49	Pa 1 +	1	5.90	27.59
Si 2 +	3	33.49	U 1 +	1	6.05	27.44
Si 2 +	3	33.49	Np 1 +	1	6.20	27.29

Si 2 +	3	33.49		Pu 1 +	1	6.06	27.43
Si 2 +	3	33.49		Am 1 +	1	5.99	27.50
Si 2 +	3	33.49		Cm 1 +	1	6.02	27.47
Si 2 +	3	33.49		Bk 1 +	1	6.23	27.26
Si 2 +	3	33.49		Cf 1 +	1	6.30	27.19
Si 2 +	3	33.49		Es 1 +	1	6.42	27.07
S 4 +	5	72.68		Si 4 +	4	45.14	27.54
Sc 3 +	4	73.47		Si 4 +	4	45.14	28.33
Mn 4 +	5	72.40		Si 4 +	4	45.14	27.26
Si 3 +	4	45.14		Co 2 +	2	17.06	28.08
Si 3 +	4	45.14		Zn 2 +	2	17.96	27.18
Si 3 +	4	45.14		Ru 2 +	2	16.76	28.38
Si 3 +	4	45.14		Rh 2 +	2	18.08	27.06
Si 3 +	4	45.14		Cd 2 +	2	16.91	28.23
Sn 4 +	5	72.28		Si 4 +	4	45.14	27.14
Si 3 +	4	45.14		Bi 2 +	2	16.69	28.45
Si 4 +	5	166.77		Cu 7 +	7	139.00	27.77
Nb 3 +	4	38.30		P 1 +	1	10.49	27.81
Pr 3 +	4	38.98		P 1 +	1	10.49	28.49
S 3 +	4	47.30		P 2 +	2	19.73	27.57
Br 3 +	4	47.30		P 2 +	2	19.73	27.57
P 3 +	4	51.37		S 2 +	2	23.33	28.04
P 3 +	4	51.37		Cl 2 +	2	23.81	27.56
Co 4 +	5	79.50		P 4 +	4	51.37	28.13
P 3 +	4	51.37		Kr 2 +	2	24.36	27.01
Kr 5 +	6	78.50		P 4 +	4	51.37	27.13
P 3 +	4	51.37		Zr 3 +	3	22.99	28.38
P 3 +	4	51.37		Sm 3 +	3	23.40	27.97
P 3 +	4	51.37		Tm 3 +	3	23.68	27.69
P 3 +	4	51.37		Hf 3 +	3	23.30	28.07
P 4 +	5	65.02		Cu 3 +	3	36.83	28.19
Ge 4 +	5	93.50		P 5 +	5	65.02	28.48
P 4 +	5	65.02		Kr 3 +	3	36.95	28.07
Y 5 +	6	93.00		P 5 +	5	65.02	27.98
P 4 +	5	65.02		Cd 3 +	3	37.48	27.54
P 4 +	5	65.02		Te 4 +	4	37.41	27.61

P 4 +	5	65.02		Ce 4 +	4	36.76	28.27
P 5 +	6	220.43		Br 8 +	8	192.80	27.63
P 7 +	8	309.41		S 7 +	7	280.93	28.48
Nb 3 +	4	38.30		S 1 +	1	10.36	27.94
Cd 2 +	3	37.48		S 1 +	1	10.36	27.12
Te 3 +	4	37.41		S 1 +	1	10.36	27.05
Ca 2 +	3	50.91		S 2 +	2	23.33	27.58
Mn 3 +	4	51.20		S 2 +	2	23.33	27.87
Co 3 +	4	51.30		S 2 +	2	23.33	27.97
Nb 4 +	5	50.55		S 2 +	2	23.33	27.22
S 2 +	3	34.83		Sc 1 +	1	6.54	28.29
S 2 +	3	34.83		Ti 1 +	1	6.82	28.01
S 2 +	3	34.83		V 1 +	1	6.74	28.09
S 2 +	3	34.83		Cr 1 +	1	6.77	28.06
S 2 +	3	34.83		Mn 1 +	1	7.43	27.40
S 2 +	3	34.83		Ni 1 +	1	7.64	27.20
S 2 +	3	34.83		Cu 1 +	1	7.73	27.10
S 2 +	3	34.83		Y 1 +	1	6.38	28.45
S 2 +	3	34.83		Zr 1 +	1	6.84	27.99
S 2 +	3	34.83		Nb 1 +	1	6.88	27.95
S 2 +	3	34.83		Mo 1 +	1	7.10	27.73
S 2 +	3	34.83		Tc 1 +	1	7.28	27.55
S 2 +	3	34.83		Ru 1 +	1	7.37	27.46
S 2 +	3	34.83		Rh 1 +	1	7.46	27.37
S 2 +	3	34.83		Ag 1 +	1	7.58	27.25
S 2 +	3	34.83		Sn 1 +	1	7.34	27.49
S 2 +	3	34.83		Hf 1 +	1	6.60	28.23
S 2 +	3	34.83		Pb 1 +	1	7.42	27.41
S 2 +	3	34.83		Bi 1 +	1	7.29	27.54
S 2 +	3	34.83		Es 1 +	1	6.42	28.41
Ar 4 +	5	75.02		S 4 +	4	47.30	27.72
Fe 4 +	5	75.00		S 4 +	4	47.30	27.70
Ni 4 +	5	75.50		S 4 +	4	47.30	28.20
S 3 +	4	47.30		Cu 2 +	2	20.29	27.01
S 3 +	4	47.30		Pd 2 +	2	19.43	27.87
S 3 +	4	47.30		In 2 +	2	18.87	28.43

S 3 +	4	47.30	I 2 +	2	19.13	28.17
S 3 +	4	47.30	La 3 +	3	19.18	28.12
S 3 +	4	47.30	Ce 3 +	3	20.20	27.10
K 5 +	6	100.00	S 5 +	5	72.68	27.32
S 4 +	5	72.68	Sb 4 +	4	44.20	28.48
S 4 +	5	72.68	Lu 4 +	4	45.19	27.49
S 4 +	5	72.68	Bi 4 +	4	45.30	27.38
S 5 +	6	88.05	Ar 4 +	4	59.81	28.24
S 5 +	6	88.05	K 4 +	4	60.91	27.14
S 5 +	6	88.05	Br 5 +	5	59.70	28.35
Y 6 +	7	116.00	S 6 +	6	88.05	27.95
Ar 2 +	3	40.74	Cl 1 +	1	12.97	27.77
Rb 2 +	3	40.00	Cl 1 +	1	12.97	27.03
Sn 3 +	4	40.73	Cl 1 +	1	12.97	27.77
Nd 3 +	4	40.41	Cl 1 +	1	12.97	27.44
Pm 3 +	4	41.10	Cl 1 +	1	12.97	28.13
Sm 3 +	4	41.40	Cl 1 +	1	12.97	28.43
Ca 2 +	3	50.91	Cl 2 +	2	23.81	27.10
Mn 3 +	4	51.20	Cl 2 +	2	23.81	27.39
Co 3 +	4	51.30	Cl 2 +	2	23.81	27.49
Cl 4 +	5	67.80	Cl 3 +	3	39.61	28.19
Cl 2 +	3	39.61	Ca 2 +	2	11.87	27.74
Ca 3 +	4	67.10	Cl 3 +	3	39.61	27.49
Cl 2 +	3	39.61	Br 1 +	1	11.81	27.80
Cl 2 +	3	39.61	Y 2 +	2	12.24	27.37
Mo 5 +	6	68.00	Cl 3 +	3	39.61	28.39
Cl 2 +	3	39.61	Xe 1 +	1	12.13	27.48
Cl 2 +	3	39.61	Eu 2 +	2	11.24	28.37
Cl 2 +	3	39.61	Gd 2 +	2	12.09	27.52
Cl 2 +	3	39.61	Tb 2 +	2	11.52	28.09
Cl 2 +	3	39.61	Dy 2 +	2	11.67	27.94
Cl 2 +	3	39.61	Ho 2 +	2	11.80	27.81
Cl 2 +	3	39.61	Er 2 +	2	11.93	27.68
Cl 2 +	3	39.61	Tm 2 +	2	12.05	27.56
Cl 2 +	3	39.61	Yb 2 +	2	12.18	27.43
Se 5 +	6	81.70	Cl 4 +	4	53.46	28.24

	Zr 4 +	5	81.50	Cl 4 +	4	53.46	28.04
	Cl 3 +	4	53.46	Nb 3 +	3	25.04	28.42
	Cl 3 +	4	53.46	Sb 3 +	3	25.30	28.16
	Cl 3 +	4	53.46	Cs 2 +	2	25.10	28.36
5	Cl 3 +	4	53.46	Yb 3 +	3	25.03	28.43
	Cl 3 +	4	53.46	Bi 3 +	3	25.56	27.90
	Cl 4 +	5	67.80	Cl 3 +	3	39.61	28.19
	Cl 4 +	5	67.80	Ar 3 +	3	40.74	27.06
	Mn 5 +	6	95.00	Cl 5 +	5	67.80	27.20
10	Cl 4 +	5	67.80	Zn 3 +	3	39.72	28.08
	Cl 4 +	5	67.80	Rb 3 +	3	40.00	27.80
	Cl 4 +	5	67.80	Sn 4 +	4	40.73	27.07
	Cl 4 +	5	67.80	Nd 4 +	4	40.41	27.39
	Cl 4 +	5	67.80	Tb 4 +	4	39.80	28.00
15	Ar 6 +	7	124.32	Cl 6 +	6	97.03	27.29
	Cl 5 +	6	97.03	Cr 5 +	5	69.30	27.73
	Fe 6 +	7	125.00	Cl 6 +	6	97.03	27.97
	Nb 6 +	7	125.00	Cl 6 +	6	97.03	27.97
	Cl 5 +	6	97.03	Pb 5 +	5	68.80	28.23
20	Ti 3 +	4	43.27	Ar 1 +	1	15.76	27.51
	Se 3 +	4	42.94	Ar 1 +	1	15.76	27.19
	Sr 2 +	3	43.60	Ar 1 +	1	15.76	27.84
	Sb 3 +	4	44.20	Ar 1 +	1	15.76	28.44
	Gd 3 +	4	44.00	Ar 1 +	1	15.76	28.24
25	Yb 3 +	4	43.70	Ar 1 +	1	15.76	27.94
	Fe 3 +	4	54.80	Ar 2 +	2	27.63	27.17
	Ni 3 +	4	54.90	Ar 2 +	2	27.63	27.27
	Cu 3 +	4	55.20	Ar 2 +	2	27.63	27.57
	Sb 4 +	5	56.00	Ar 2 +	2	27.63	28.37
30	Bi 4 +	5	56.00	Ar 2 +	2	27.63	28.37
	Ar 2 +	3	40.74	Sc 2 +	2	12.80	27.94
	Ar 2 +	3	40.74	Ti 2 +	2	13.58	27.16
	Se 4 +	5	68.30	Ar 3 +	3	40.74	27.56
	Ar 2 +	3	40.74	Zr 2 +	2	13.13	27.61
35	Mo 5 +	6	68.00	Ar 3 +	3	40.74	27.26
	Pb 4 +	5	68.80	Ar 3 +	3	40.74	28.06

Ar 3 +	4	59.81		K 2 +	2	31.63	28.19
Ar 3 +	4	59.81		Xe 3 +	3	32.10	27.71
Ar 3 +	4	59.81		Pb 3 +	3	31.94	27.87
Bi 5 +	6	88.30		Ar 4 +	4	59.81	28.49
Ar 4 +	5	75.02		V 4 +	4	46.71	28.31
Cu 5 +	6	103.00		Ar 5 +	5	75.02	27.98
Ar 4 +	5	75.02		Br 4 +	4	47.30	27.72
Br 6 +	7	103.00		Ar 5 +	5	75.02	27.98
Nb 5 +	6	102.60		Ar 5 +	5	75.02	27.58
Ti 5 +	6	119.36		Ar 6 +	6	91.01	28.35
Mn 6 +	7	119.27		Ar 6 +	6	91.01	28.26
Ar 5 +	6	91.01		Ga 4 +	4	64.00	27.01
Ar 5 +	6	91.01		As 5 +	5	63.63	27.38
Ar 7 +	8	143.46		Y 7 +	7	116.00	27.46
K 1 +	2	31.63		K 1 +	1	4.34	27.28
Xe 2 +	3	32.10		K 1 +	1	4.34	27.76
Pb 2 +	3	31.94		K 1 +	1	4.34	27.60
K 1 +	2	31.63		K 1 +	1	4.34	27.28
Zn 3 +	4	59.40		K 2 +	2	31.63	27.78
Br 4 +	5	59.70		K 2 +	2	31.63	28.08
K 1 +	2	31.63		Rb 1 +	1	4.18	27.45
Te 4 +	5	58.75		K 2 +	2	31.63	27.13
K 1 +	2	31.63		Cs 1 +	1	3.89	27.73
Sc 3 +	4	73.47		K 3 +	3	45.72	27.75
K 2 +	3	45.72		Ni 2 +	2	18.17	27.55
K 2 +	3	45.72		Zn 2 +	2	17.96	27.76
K 2 +	3	45.72		As 2 +	2	18.63	27.09
K 2 +	3	45.72		Rh 2 +	2	18.08	27.64
K 2 +	3	45.72		Te 2 +	2	18.60	27.12
K 2 +	3	45.72		Pt 2 +	2	18.56	27.16
K 3 +	4	60.91		Mn 3 +	3	33.67	27.24
K 3 +	4	60.91		Co 3 +	3	33.50	27.41
Br 5 +	6	88.60		K 4 +	4	60.91	27.69
K 3 +	4	60.91		Pd 3 +	3	32.93	27.98
K 3 +	4	60.91		I 3 +	3	33.00	27.91
K 3 +	4	60.91		Hf 4 +	4	33.33	27.58

Bi 5 +	6	88.30	
Sc 5 +	6	111.10	
K 4 +	5	82.66	
K 4 +	5	82.66	
K 4 +	5	82.66	
Kr 6 +	7	111.00	
Ca 6 +	7	127.70	
V 5 +	6	128.12	
K 5 +	6	100.00	
As 5 +	6	127.60	
K 5 +	6	100.00	
K 5 +	6	100.00	
K 7 +	8	154.86	
K 7 +	8	154.86	
K 7 +	8	154.86	
Mn 2 +	3	33.67	
Co 2	3	33.50	
Ge 2 +	3	34.22	
Zr 3 +	4	34.34	
Hf 3 +	4	33.33	
Hg 2 +	3	34.20	
Zn 2 +	3	39.72	
Rb 2 +	3	40.00	
Pr 3 +	4	38.98	
Tb 3 +	4	39.80	
Kr 5 +	6	78.50	
Ca 2 +	3	50.91	
Ca 2 +	3	50.91	
Ca 2 +	3	50.91	
Ca 2 +	3	50.91	
Ca 2 +	3	50.91	
Ca 2 +	3	50.91	
Mn 5 +	6	95.00	
Ca 3 +	4	67.10	
Ca 3 +	4	67.10	
K 4 +	4	60.91	27.39
K 5 +	5	82.66	28.44
Fe 4 +	4	54.80	27.86
Ni 4 +	4	54.90	27.76
Cu 4 +	4	55.20	27.46
K 5 +	5	82.66	28.34
K 6 +	6	100.00	27.70
K 6 +	6	100.00	28.12
Mn 5 +	5	72.40	27.60
K 6 +	6	100.00	27.60
Sr 5 +	5	71.60	28.40
Sn 5 +	5	72.28	27.72
Ca 7 +	7	127.70	27.16
As 6 +	6	127.60	27.26
Mo 7 +	7	126.80	28.06
Ca 1 +	1	6.11	27.55
Ca 1 +	1	6.11	27.39
Ca 1 +	1	6.11	28.11
Ca 1 +	1	6.11	28.23
Ca 1 +	1	6.11	27.22
Ca 1 +	1	6.11	28.09
Ca 2 +	2	11.87	27.85
Ca 2 +	2	11.87	28.13
Ca 2 +	2	11.87	27.11
Ca 2 +	2	11.87	27.93
Ca 3 +	3	50.91	27.59
Zr 3 +	3	22.99	27.92
Sm 3 +	3	23.40	27.51
Dy 3 +	3	22.80	28.11
Ho 3 +	3	22.84	28.07
Er 3 +	3	22.74	28.17
Tm 3 +	3	23.68	27.23
Hf 3 +	3	23.30	27.61
Ca 4 +	4	67.10	27.90
Zn 3 +	3	39.72	27.38
Rb 3 +	3	40.00	27.10

Ca 3 +	4	67.10		Pr 4 +	4	38.98	28.12
Ca 3 +	4	67.10		Tb 4 +	4	39.80	27.30
Ca 4 +	5	84.41		Sr 4 +	4	57.00	27.41
Ca 4 +	5	84.41		Sb 5 +	5	56.00	28.41
Ca 4 +	5	84.41		Bi 5 +	5	56.00	28.41
Ca 5 +	6	108.78		Se 6 +	6	81.70	27.08
Rb 7 +	8	136.00		Ca 6 +	6	108.78	27.22
Ca 5 +	6	108.78		Zr 5 +	5	81.50	27.28
Te 6 +	7	137.00		Ca 6 +	6	108.78	28.22
Ca 6 +	7	127.70		Ti 5 +	5	99.22	28.48
Se 6 +	7	155.40		Ca 7 +	7	127.70	27.70
Ca 7 +	8	147.24		Ti 6 +	6	119.36	27.88
Ca 7 +	8	147.24		Mn 7 +	7	119.27	27.97
Mn 2 +	3	33.67		Sc 1 +	1	6.54	27.13
Ge 2 +	3	34.22		Sc 1 +	1	6.54	27.68
Zr 3 +	4	34.34		Sc 1 +	1	6.54	27.80
Ag 2 +	3	34.83		Sc 1 +	1	6.54	28.29
Hg 2 +	3	34.20		Sc 1 +	1	6.54	27.66
Rb 2 +	3	40.00		Sc 2 +	2	12.80	27.20
Sn 3 +	4	40.73		Sc 2 +	2	12.80	27.93
Nd 3 +	4	40.41		Sc 2 +	2	12.80	27.61
Pm 3 +	4	41.10		Sc 2 +	2	12.80	28.30
Kr 3 +	4	52.50		Sc 3 +	3	24.76	27.74
Rb 3 +	4	52.60		Sc 3 +	3	24.76	27.84
Sc 3 +	4	73.47		Ge 4 +	4	45.71	27.76
Sc 3 +	4	73.47		Mo 4 +	4	46.40	27.07
Sc 3 +	4	73.47		Lu 4 +	4	45.19	28.28
Sc 3 +	4	73.47		Bi 4 +	4	45.30	28.17
Ti 5 +	6	119.36		Sc 5 +	5	91.66	27.70
Mn 6 +	7	119.27		Sc 5 +	5	91.66	27.61
Sc 4 +	5	91.66		Ga 4 +	4	64.00	27.66
Sc 4 +	5	91.66		As 5 +	5	63.63	28.03
Cu 6 +	7	139.00		Sc 6 +	6	111.10	27.90
Cu 7 +	8	166.00		Sc 7 +	7	138.00	28.00
Ni 2 +	3	35.17		Ti 1 +	1	6.82	28.35
Ge 2 +	3	34.22		Ti 1 +	1	6.82	27.40

Zr 3 +	4	34.34	Ti 1 +	1	6.82	27.52
Ag 2 +	3	34.83	Ti 1 +	1	6.82	28.01
Hg 2 +	3	34.20	Ti 1 +	1	6.82	27.38
Sn 3 +	4	40.73	Ti 2 +	2	13.58	27.15
Pm 3 +	4	41.10	Ti 2 +	2	13.58	27.52
Sm 3 +	4	41.40	Ti 2 +	2	13.58	27.82
Dy 3 +	4	41.50	Ti 2 +	2	13.58	27.92
Fe 3 +	4	54.80	Ti 3 +	3	27.49	27.31
Ni 3 +	4	54.90	Ti 3 +	3	27.49	27.41
Cu 3 +	4	55.20	Ti 3 +	3	27.49	27.71
Ti 3 +	4	43.27	Mn 2 +	2	15.64	27.63
Ti 3 +	4	43.27	Fe 2 +	2	16.18	27.09
Ti 3 +	4	43.27	Ge 2 +	2	15.93	27.33
Rb 4 +	5	71.00	Ti 4 +	4	43.27	27.73
Sr 4 +	5	71.60	Ti 4 +	4	43.27	28.33
Ti 3 +	4	43.27	Mo 2 +	2	16.15	27.12
Ti 3 +	4	43.27	Tc 2 +	2	15.26	28.01
Te 5 +	6	70.70	Ti 4 +	4	43.27	27.43
Ti 3 +	4	43.27	Hf 2 +	2	14.90	28.37
Ti 3 +	4	43.27	Pb 2 +	2	15.03	28.23
As 5 +	6	127.60	Ti 5 +	5	99.22	28.38
Ti 4 +	5	99.22	Rb 5 +	5	71.00	28.22
Ti 4 +	5	99.22	Sr 5 +	5	71.60	27.62
Mo 6 +	7	126.80	Ti 5 +	5	99.22	27.58
Ti 7 +	8	168.50	Ti 7 +	7	140.80	27.70
Ti 7 +	8	168.50	Ti 7 +	7	140.80	27.70
Mn 7 +	8	196.46	Ti 8 +	8	168.50	27.96
Ni 2 +	3	35.17	V 1 +	1	6.74	28.43
Ge 2 +	3	34.22	V 1 +	1	6.74	27.48
Zr 3 +	4	34.34	V 1 +	1	6.74	27.60
Ag 2 +	3	34.83	V 1 +	1	6.74	28.09
Hg 2 +	3	34.20	V 1 +	1	6.74	27.46
Se 3 +	4	42.94	V 2 +	2	14.65	28.29
Eu 3 +	4	42.60	V 2 +	2	14.65	27.95
Ho 3 +	4	42.50	V 2 +	2	14.65	27.85
Er 3 +	4	42.60	V 2 +	2	14.65	27.95

Tm 3 +	4	42.70	V 2 +	2	14.65	28.05
Pb 3 +	4	42.32	V 2 +	2	14.65	27.67
Sr 3 +	4	57.00	V 3 +	3	29.31	27.69
Fe 4 +	5	75.00	V 4 +	4	46.71	28.29
V 3 +	4	46.71	As 2 +	2	18.63	28.07
V 3 +	4	46.71	Pd 2 +	2	19.43	27.28
V 3 +	4	46.71	In 2 +	2	18.87	27.84
V 3 +	4	46.71	Te 2 +	2	18.60	28.11
V 3 +	4	46.71	I 2 +	2	19.13	27.58
V 3 +	4	46.71	La 3 +	3	19.18	27.53
V 3 +	4	46.71	Pt 2 +	2	18.56	28.14
V 3 +	4	46.71	Hg 2 +	2	18.76	27.95
V 4 +	5	65.23	Cu 3 +	3	36.83	28.40
Ge 4 +	5	93.50	V 5 +	5	65.23	28.27
V 4 +	5	65.23	Kr 3 +	3	36.95	28.28
Y 5 +	6	93.00	V 5 +	5	65.23	27.77
V 4 +	5	65.23	Cd 3 +	3	37.48	27.75
V 4 +	5	65.23	Te 4 +	4	37.41	27.82
V 4 +	5	65.23	Ce 4 +	4	36.76	28.47
Se 6 +	7	155.40	V 6 +	6	128.12	27.28
V 6 +	7	150.17	Sr 8 +	8	122.30	27.87
Ni 2 +	3	35.17	Cr 1 +	1	6.77	28.40
Ge 2 +	3	34.22	Cr 1 +	1	6.77	27.45
Zr 3 +	4	34.34	Cr 1 +	1	6.77	27.57
Ag 2 +	3	34.83	Cr 1 +	1	6.77	28.06
Hg 2 +	3	34.20	Cr 1 +	1	6.77	27.43
Sr 2 +	3	43.60	Cr 2 +	2	16.50	27.10
Sb 3 +	4	44.20	Cr 2 +	2	16.50	27.70
Gd 3 +	4	44.00	Cr 2 +	2	16.50	27.50
Yb 3 +	4	43.70	Cr 2 +	2	16.50	27.20
Zn 3 +	4	59.40	Cr 3 +	3	30.96	28.44
Te 4 +	5	58.75	Cr 3 +	3	30.96	27.79
Cr 2 +	3	30.96	Cs 1 +	1	3.89	27.07
Cr 3 +	4	49.10	Se 2 +	2	21.19	27.91
Cr 3 +	4	49.10	Br 2 +	2	21.80	27.30
Y 4 +	5	77.00	Cr 4 +	4	49.10	27.90

Cr 3 +	4	49.10	
Cr 3 +	4	49.10	
Cr 3 +	4	49.10	
Cr 3 +	4	49.10	
Cr 3 +	4	49.10	
Cr 3 +	4	49.10	
Cr 4 +	5	69.30	
Cr 4 +	5	69.30	
Cr 4 +	5	69.30	
Cr 6 +	7	161.10	
Cr 6 +	7	161.10	
Cr 7 +	8	184.70	
Ni 2 +	3	35.17	
Ag 2 +	3	34.83	
Se 3 +	4	42.94	
Sr 2 +	3	43.60	
Gd 3 +	4	44.00	
Tm 3 +	4	42.70	
Yb 3 +	4	43.70	
Mn 2 +	3	33.67	
Mn 2 +	3	33.67	
Mn 2 +	3	33.67	
Y 3 +	4	61.80	
Mo 4 +	5	61.20	
Mn 2 +	3	33.67	
Mn 2 +	3	33.67	
Mn 2 +	3	33.67	
Mn 2 +	3	33.67	
Mn 2 +	3	33.67	
Mn 2 +	3	33.67	
Mn 2 +	3	33.67	
Mn 2 +	3	33.67	
Mn 2 +	3	33.67	
Mn 2 +	3	33.67	
Mn 2 +	3	33.67	
Mn 2 +	3	33.67	
Ag 2 +	2	21.49	27.61
Xe 2 +	2	21.21	27.89
Pr 3 +	3	21.62	27.48
Gd 3 +	3	20.63	28.47
Tb 3 +	3	21.91	27.19
Lu 3 +	3	20.96	28.14
Pm 4 +	4	41.10	28.20
Sm 4 +	4	41.40	27.90
Dy 4 +	4	41.50	27.80
Ni 7 +	7	133.00	28.10
Zn 7 +	7	134.00	27.10
Co 8 +	8	157.00	27.70
Mn 1 +	1	7.43	27.73
Mn 1 +	1	7.43	27.40
Mn 2 +	2	15.64	27.30
Mn 2 +	2	15.64	27.96
Mn 2 +	2	15.64	28.36
Mn 2 +	2	15.64	27.06
Mn 2 +	2	15.64	28.06
Ga 1 +	1	6.00	27.67
Sr 1 +	1	5.70	27.97
Y 1 +	1	6.38	27.29
Mn 3 +	3	33.67	28.13
Mn 3 +	3	33.67	27.53
In 1 +	1	5.79	27.88
Ba 1 +	1	5.21	28.45
La 1 +	1	5.58	28.09
Ce 1 +	1	5.47	28.20
Pr 1 +	1	5.42	28.24
Nd 1 +	1	5.49	28.18
Pm 1 +	1	5.55	28.11
Sm 1 +	1	5.63	28.04
Eu 1 +	1	5.67	28.00
Gd 1 +	1	6.14	27.53
Tb 1 +	1	5.85	27.82
Dy 1 +	1	5.93	27.74

	Mn 2 +	3	33.67	Ho 1 +	1	6.02	27.65
	Mn 2 +	3	33.67	Er 1 +	1	6.10	27.57
	Mn 2 +	3	33.67	Tm 1 +	1	6.18	27.48
	Mn 2 +	3	33.67	Yb 1 +	1	6.25	27.41
5	Mn 2 +	3	33.67	Lu 1 +	1	5.43	28.24
	Mn 2 +	3	33.67	Hf 1 +	1	6.60	27.07
	Mn 2 +	3	33.67	Tl 1 +	1	6.11	27.56
	Mn 2 +	3	33.67	Ra 1 +	1	5.28	28.39
	Mn 2 +	3	33.67	Ac 1 +	1	5.20	28.47
10	Mn 2 +	3	33.67	Th 1 +	1	6.10	27.57
	Mn 2 +	3	33.67	Pa 1 +	1	5.90	27.77
	Mn 2 +	3	33.67	U 1 +	1	6.05	27.62
	Mn 2 +	3	33.67	Np 1 +	1	6.20	27.47
	Mn 2 +	3	33.67	Pu 1 +	1	6.06	27.61
15	Mn 2 +	3	33.67	Am 1 +	1	5.99	27.68
	Mn 2 +	3	33.67	Cm 1 +	1	6.02	27.65
	Mn 2 +	3	33.67	Bk 1 +	1	6.23	27.44
	Mn 2 +	3	33.67	Cf 1 +	1	6.30	27.37
	Mn 2 +	3	33.67	Es 1 +	1	6.42	27.25
20	Co 4 +	5	79.50	Mn 4 +	4	51.20	28.30
	Kr 5 +	6	78.50	Mn 4 +	4	51.20	27.30
	Mn 3 +	4	51.20	Zr 3 +	3	22.99	28.21
	Mn 3 +	4	51.20	Sm 3 +	3	23.40	27.80
	Mn 3 +	4	51.20	Dy 3 +	3	22.80	28.40
25	Mn 3 +	4	51.20	Ho 3 +	3	22.84	28.36
	Mn 3 +	4	51.20	Er 3 +	3	22.74	28.46
	Mn 3 +	4	51.20	Tm 3 +	3	23.68	27.52
	Mn 3 +	4	51.20	Hf 3 +	3	23.30	27.90
	Mn 4 +	5	72.40	Sb 4 +	4	44.20	28.20
30	Mn 4 +	5	72.40	Gd 4 +	4	44.00	28.40
	Mn 4 +	5	72.40	Lu 4 +	4	45.19	27.21
	Mn 4 +	5	72.40	Bi 4 +	4	45.30	27.10
	Sr 7 +	8	122.30	Mn 6 +	6	95.00	27.30
	Mn 6 +	7	119.27	Sr 6 +	6	90.80	28.47
35	Ni 2 +	3	35.17	Fe 1 +	1	7.87	27.30
	Br 2 +	3	36.00	Fe 1 +	1	7.87	28.13

	Sr 2 +	3	43.60	Fe 2 +	2	16.18	27.42
	Sb 3 +	4	44.20	Fe 2 +	2	16.18	28.02
	Gd 3 +	4	44.00	Fe 2 +	2	16.18	27.82
	Yb 3 +	4	43.70	Fe 2 +	2	16.18	27.52
5	Te 4 +	5	58.75	Fe 3 +	3	30.65	28.10
	Zn 4 +	5	82.60	Fe 4 +	4	54.80	27.80
	Fe 3 +	4	54.80	Rb 2 +	2	27.28	27.52
	Fe 3 +	4	54.80	Mo 3 +	3	27.16	27.64
	Cu 5 +	6	103.00	Fe 5 +	5	75.00	28.00
10	Fe 4 +	5	75.00	Br 4 +	4	47.30	27.70
	Br 6 +	7	103.00	Fe 5 +	5	75.00	28.00
	Nb 5 +	6	102.60	Fe 5 +	5	75.00	27.60
	Fe 5 +	6	99.00	Rb 5 +	5	71.00	28.00
	Fe 5 +	6	99.00	Sr 5 +	5	71.60	27.40
15	Mo 6 +	7	126.80	Fe 6 +	6	99.00	27.80
	Fe 5 +	6	99.00	Te 6 +	6	70.70	28.30
	Mo 7 +	8	153.00	Fe 7 +	7	125.00	28.00
	Ni 2 +	3	35.17	Co 1 +	1	7.86	27.31
	Br 2 +	3	36.00	Co 1 +	1	7.86	28.14
20	Sb 3 +	4	44.20	Co 2 +	2	17.06	27.14
	Lu 3 +	4	45.19	Co 2 +	2	17.06	28.13
	Bi 3 +	4	45.30	Co 2 +	2	17.06	28.24
	Co 2 +	3	33.50	Ga 1 +	1	6.00	27.50
	Co 2 +	3	33.50	Sr 1 +	1	5.70	27.81
25	Co 2 +	3	33.50	Y 1 +	1	6.38	27.12
	Y 3 +	4	61.80	Co 3 +	3	33.50	28.30
	Mo 4 +	5	61.20	Co 3 +	3	33.50	27.70
	Co 2 +	3	33.50	In 1 +	1	5.79	27.71
	Co 2 +	3	33.50	Ba 1 +	1	5.21	28.29
30	Co 2 +	3	33.50	La 1 +	1	5.58	27.92
	Co 2 +	3	33.50	Ce 1 +	1	5.47	28.03
	Co 2 +	3	33.50	Pr 1 +	1	5.42	28.08
	Co 2 +	3	33.50	Nd 1 +	1	5.49	28.01
	Co 2 +	3	33.50	Pm 1 +	1	5.55	27.95
35	Co 2 +	3	33.50	Sm 1 +	1	5.63	27.87
	Co 2 +	3	33.50	Eu 1 +	1	5.67	27.83

Co 2 +	3	33.50	Gd 1 +	1	6.14	27.36
Co 2 +	3	33.50	Tb 1 +	1	5.85	27.65
Co 2 +	3	33.50	Dy 1 +	1	5.93	27.57
Co 2 +	3	33.50	Ho 1 +	1	6.02	27.48
Co 2 +	3	33.50	Er 1 +	1	6.10	27.40
Co 2 +	3	33.50	Tm 1 +	1	6.18	27.32
Co 2 +	3	33.50	Yb 1 +	1	6.25	27.25
Co 2 +	3	33.50	Lu 1 +	1	5.43	28.07
Co 2 +	3	33.50	Tl 1 +	1	6.11	27.39
Co 2 +	3	33.50	Ra 1 +	1	5.28	28.22
Co 2 +	3	33.50	Ac 1 +	1	5.20	28.30
Co 2 +	3	33.50	Th 1 +	1	6.10	27.40
Co 2 +	3	33.50	Pa 1 +	1	5.90	27.60
Co 2 +	3	33.50	U 1 +	1	6.05	27.45
Co 2 +	3	33.50	Np 1 +	1	6.20	27.30
Co 2 +	3	33.50	Pu 1 +	1	6.06	27.44
Co 2 +	3	33.50	Am 1 +	1	5.99	27.51
Co 2 +	3	33.50	Cm 1 +	1	6.02	27.48
Co 2 +	3	33.50	Bk 1 +	1	6.23	27.27
Co 2 +	3	33.50	Cf 1 +	1	6.30	27.20
Co 2 +	3	33.50	Es 1 +	1	6.42	27.08
Co 4 +	5	79.50	Co 4 +	4	51.30	28.20
Kr 5 +	6	78.50	Co 4 +	4	51.30	27.20
Co 3 +	4	51.30	Zr 3 +	3	22.99	28.31
Co 3 +	4	51.30	Sm 3 +	3	23.40	27.90
Co 3 +	4	51.30	Ho 3 +	3	22.84	28.46
Co 3 +	4	51.30	Tm 3 +	3	23.68	27.62
Co 3 +	4	51.30	Hf 3 +	3	23.30	28.00
Co 4 +	5	79.50	Co 4 +	4	51.30	28.20
Co 7 +	8	157.00	Co 7 +	7	129.00	28.00
Co 7 +	8	157.00	Co 7 +	7	129.00	28.00
Co 7 +	8	157.00	Y 8 +	8	129.00	28.00
Ni 2 +	3	35.17	Ni 1 +	1	7.64	27.53
Br 2 +	3	36.00	Ni 1 +	1	7.64	28.36
Ag 2 +	3	34.83	Ni 1 +	1	7.64	27.20
Ge 3 +	4	45.71	Ni 2 +	2	18.17	27.54

Mo 3 +	4	46.40	Ni 2 +	2	18.17	28.23
Lu 3 +	4	45.19	Ni 2 +	2	18.17	27.02
Bi 3 +	4	45.30	Ni 2 +	2	18.17	27.13
Ni 2 +	3	35.17	Ni 1 +	1	7.64	27.53
Ni 2 +	3	35.17	Cu 1 +	1	7.73	27.44
Ni 2 +	3	35.17	Ge 1 +	1	7.90	27.27
As 4 +	5	63.63	Ni 3 +	3	35.17	28.46
Ni 2 +	3	35.17	Zr 1 +	1	6.84	28.33
Ni 2 +	3	35.17	Nb 1 +	1	6.88	28.29
Ni 2 +	3	35.17	Mo 1 +	1	7.10	28.07
Ni 2 +	3	35.17	Tc 1 +	1	7.28	27.89
Ni 2 +	3	35.17	Ru 1 +	1	7.37	27.80
Ni 2 +	3	35.17	Rh 1 +	1	7.46	27.71
Ni 2 +	3	35.17	Ag 1 +	1	7.58	27.59
Ni 2 +	3	35.17	Sn 1 +	1	7.34	27.83
Ni 2 +	3	35.17	Ta 1 +	1	7.89	27.28
Ni 2 +	3	35.17	W 1 +	1	7.98	27.19
Ni 2 +	3	35.17	Re 1 +	1	7.88	27.29
Ni 2 +	3	35.17	Pb 1 +	1	7.42	27.75
Ni 2 +	3	35.17	Bi 1 +	1	7.29	27.88
Zn 4 +	5	82.60	Ni 4 +	4	54.90	27.70
Ni 3 +	4	54.90	Rb 2 +	2	27.28	27.62
Ni 3	4	54.90	Mo 3 +	3	27.16	27.74
Cu 5 +	6	103.00	Ni 5 +	5	75.50	27.50
Ni 4 +	5	75.50	Br 4 +	4	47.30	28.20
Br 6 +	7	103.00	Ni 5 +	5	75.50	27.50
Nb 5 +	6	102.60	Ni 5 +	5	75.50	27.10
Ni 5 +	6	108.00	Cu 5 +	5	79.90	28.10
Rb 7 +	8	136.00	Ni 6 +	6	108.00	28.00
Ni 7 +	8	162.00	Zn 7 +	7	134.00	28.00
Br 2 +	3	36.00	Cu 1 +	1	7.73	28.27
Ag 2 +	3	34.83	Cu 1 +	1	7.73	27.10
Br 3 +	4	47.30	Cu 2 +	2	20.29	27.01
Cu 2 +	3	36.83	Zn 1 +	1	9.39	27.44
Ga 3 +	4	64.00	Cu 3 +	3	36.83	27.17
Cu 2 +	3	36.83	As 1 +	1	9.81	27.02

	Cu 2 +	3	36.83	Se 1 +	1	9.75	27.08
	Kr 4 +	5	64.70	Cu 3 +	3	36.83	27.87
	Cu 2 +	3	36.83	Pd 1 +	1	8.34	28.49
	Cu 2 +	3	36.83	Cd 1 +	1	8.99	27.84
5	Cu 2 +	3	36.83	Sb 1 +	1	8.64	28.19
	Cu 2 +	3	36.83	Te 1 +	1	9.01	27.82
	Cu 2 +	3	36.83	Os 1 +	1	8.70	28.13
	Cu 2 +	3	36.83	Ir 1 +	1	9.10	27.73
	Cu 2 +	3	36.83	Pt 1 +	1	9.00	27.83
10	Cu 2 +	3	36.83	Au 1 +	1	9.23	27.61
	Cu 2 +	3	36.83	Po 1 +	1	8.42	28.41
	Zn 4 +	5	82.60	Cu 4 +	4	55.20	27.40
	Cu 3 +	4	55.20	Rb 2 +	2	27.28	27.92
	Cu 3 +	4	55.20	Mo 3 +	3	27.16	28.04
15	Cu 3 +	4	55.20	In 3 +	3	28.03	27.17
	Cu 3 +	4	55.20	Te 3 +	3	27.96	27.24
	Zn 5 +	6	108.00	Cu 5 +	5	79.90	28.10
	Cu 4 +	5	79.90	Kr 4 +	4	52.50	27.40
	Cu 4 +	5	79.90	Rb 4 +	4	52.60	27.30
20	Sb 5 +	6	108.00	Cu 5 +	5	79.90	28.10
	Cu 6 +	7	139.00	Kr 7 +	7	111.00	28.00
	Kr 2 +	3	36.95	Zn 1 +	1	9.39	27.56
	Cd 2 +	3	37.48	Zn 1 +	1	9.39	28.09
	Te 3 +	4	37.41	Zn 1 +	1	9.39	28.02
25	Ce 3 +	4	36.76	Zn 1 +	1	9.39	27.36
	Ge 3 +	4	45.71	Zn 2 +	2	17.96	27.75
	Mo 3 +	4	46.40	Zn 2 +	2	17.96	28.44
	Lu 3 +	4	45.19	Zn 2 +	2	17.96	27.23
	Bi 3 +	4	45.30	Zn 2 +	2	17.96	27.34
30	Zn 2 +	3	39.72	Br 1 +	1	11.81	27.91
	Zn 2 +	3	39.72	Y 2 +	2	12.24	27.48
	Mo 5 +	6	68.00	Zn 3 +	3	39.72	28.28
	Zn 2 +	3	39.72	Xe 1 +	1	12.13	27.59
	Zn 2 +	3	39.72	Eu 2 +	2	11.24	28.48
35	Zn 2 +	3	39.72	Gd 2 +	2	12.09	27.63
	Zn 2 +	3	39.72	Tb 2 +	2	11.52	28.20

Zn 2 +	3	39.72		Dy 2 +	2	11.67	28.05
Zn 2 +	3	39.72		Ho 2 +	2	11.80	27.92
Zn 2 +	3	39.72		Er 2 +	2	11.93	27.79
Zn 2 +	3	39.72		Tm 2 +	2	12.05	27.67
Zn 2 +	3	39.72		Yb 2 +	2	12.18	27.54
Zn 3 +	4	59.40		Rh 3 +	3	31.06	28.34
Zn 3 +	4	59.40		Xe 3 +	3	32.10	27.30
Zn 3 +	4	59.40		Pb 3 +	3	31.94	27.46
Kr 6 +	7	111.00		Zn 5 +	5	82.60	28.40
Rb 7 +	8	136.00		Zn 6 +	6	108.00	28.00
Zn 6 +	7	134.00		Sr 7 +	7	106.00	28.00
Ge 2 +	3	34.22		Ga 1 +	1	6.00	28.22
Zr 3 +	4	34.34		Ga 1 +	1	6.00	28.34
I 2 +	3	33.00		Ga 1 +	1	6.00	27.00
Hf 3 +	4	33.33		Ga 1 +	1	6.00	27.33
Hg 2 +	3	34.20		Ga 1 +	1	6.00	28.20
Te 4 +	5	58.75		Ga 3 +	3	30.71	28.04
Ga 3 +	4	64.00		Br 3 +	3	36.00	28.00
Ga 3 +	4	64.00		Kr 3 +	3	36.95	27.05
Ga 3 +	4	64.00		Ce 4 +	4	36.76	27.24
Br 2 +	3	36.00		Ge 1 +	1	7.90	28.10
Se 3 +	4	42.94		Ge 2 +	2	15.93	27.01
Sr 2 +	3	43.60		Ge 2 +	2	15.93	27.67
Sb 3 +	4	44.20		Ge 2 +	2	15.93	28.27
Gd 3 +	4	44.00		Ge 2 +	2	15.93	28.07
Yb 3 +	4	43.70		Ge 2 +	2	15.93	27.77
Ge 2 +	3	34.22		Y 1 +	1	6.38	27.84
Y 3 +	4	61.80		Ge 3 +	3	34.22	27.58
Ge 2 +	3	34.22		Zr 1 +	1	6.84	27.38
Ge 2 +	3	34.22		Nb 1 +	1	6.88	27.34
Ge 2 +	3	34.22		Mo 1 +	1	7.10	27.12
Ge 2 +	3	34.22		In 1 +	1	5.79	28.43
Ge 2 +	3	34.22		Gd 1 +	1	6.14	28.08
Ge 2 +	3	34.22		Tb 1 +	1	5.85	28.37
Ge 2 +	3	34.22		Dy 1 +	1	5.93	28.29
Ge 2 +	3	34.22		Ho 1 +	1	6.02	28.20

Ge 2 +	3	34.22	Er 1 +	1	6.10	28.12
Ge 2 +	3	34.22	Tm 1 +	1	6.18	28.04
Ge 2 +	3	34.22	Yb 1 +	1	6.25	27.97
Ge 2 +	3	34.22	Hf 1 +	1	6.60	27.62
Ge 2 +	3	34.22	Tl 1 +	1	6.11	28.11
Ge 2 +	3	34.22	Th 1 +	1	6.10	28.12
Ge 2 +	3	34.22	Pa 1 +	1	5.90	28.32
Ge 2 +	3	34.22	U 1 +	1	6.05	28.17
Ge 2 +	3	34.22	Np 1 +	1	6.20	28.02
Ge 2 +	3	34.22	Pu 1 +	1	6.06	28.16
Ge 2 +	3	34.22	Am 1 +	1	5.99	28.23
Ge 2 +	3	34.22	Cm 1 +	1	6.02	28.20
Ge 2 +	3	34.22	Bk 1 +	1	6.23	27.99
Ge 2 +	3	34.22	Cf 1 +	1	6.30	27.92
Ge 2 +	3	34.22	Es 1 +	1	6.42	27.80
Ge 3 +	4	45.71	As 2 +	2	18.63	27.08
Ge 3 +	4	45.71	Rh 2 +	2	18.08	27.63
Ge 3 +	4	45.71	Te 2 +	2	18.60	27.11
Ge 3 +	4	45.71	Pt 2 +	2	18.56	27.15
Kr 2 +	3	36.95	As 1 +	1	9.81	27.14
Nb 3 +	4	38.30	As 1 +	1	9.81	28.49
Cd 2 +	3	37.48	As 1 +	1	9.81	27.67
Te 3 +	4	37.41	As 1 +	1	9.81	27.60
Mo 3 +	4	46.40	As 2 +	2	18.63	27.77
Sb 4 +	5	56.00	As 3 +	3	28.35	27.65
Bi 4 +	5	56.00	As 3 +	3	28.35	27.65
As 3 +	4	50.13	Br 2 +	2	21.80	28.33
Kr 5 +	6	78.50	As 4 +	4	50.13	28.37
As 3 +	4	50.13	Zr 3 +	3	22.99	27.14
As 3 +	4	50.13	Nd 3 +	3	22.10	28.03
As 3 +	4	50.13	Pm 3 +	3	22.30	27.83
As 3 +	4	50.13	Tb 3 +	3	21.91	28.22
As 3 +	4	50.13	Dy 3 +	3	22.80	27.33
As 3 +	4	50.13	Ho 3 +	3	22.84	27.29
As 3 +	4	50.13	Er 3 +	3	22.74	27.39
As 4 +	5	63.63	Br 3 +	3	36.00	27.63

Sr	5 +	6	90.80	As	5 +	5	63.63	27.17
Se	6 +	7	155.40	As	6 +	6	127.60	27.80
As	5 +	6	127.60	Rb	7 +	7	99.20	28.40
Kr	2 +	3	36.95	Se	1 +	1	9.75	27.20
Cd	2 +	3	37.48	Se	1 +	1	9.75	27.73
Te	3 +	4	37.41	Se	1 +	1	9.75	27.66
Ce	3 +	4	36.76	Se	1 +	1	9.75	27.01
Te	4 +	5	58.75	Se	3 +	3	30.82	27.93
Rb	4 +	5	71.00	Se	4 +	4	42.94	28.06
Se	3 +	4	42.94	Tc	2 +	2	15.26	27.68
Se	3 +	4	42.94	Sn	2 +	2	14.63	28.31
Te	5 +	6	70.70	Se	4 +	4	42.94	27.76
Se	3 +	4	42.94	Hf	2 +	2	14.90	28.04
Se	3 +	4	42.94	Pb	2 +	2	15.03	27.91
Se	4 +	5	68.30	Rb	3 +	3	40.00	28.30
Se	4 +	5	68.30	Sn	4 +	4	40.73	27.57
Se	4 +	5	68.30	Nd	4 +	4	40.41	27.89
Se	4 +	5	68.30	Pm	4 +	4	41.10	27.20
Se	5 +	6	81.70	In	4 +	4	54.00	27.70
Rb	2 +	3	40.00	Br	1 +	1	11.81	28.19
Pr	3 +	4	38.98	Br	1 +	1	11.81	27.17
Tb	3 +	4	39.80	Br	1 +	1	11.81	27.99
La	3 +	4	49.95	Br	2 +	2	21.80	28.15
Br	2 +	3	36.00	Pd	1 +	1	8.34	27.66
Br	2 +	3	36.00	Ag	1 +	1	7.58	28.42
Br	2 +	3	36.00	Cd	1 +	1	8.99	27.01
Br	2 +	3	36.00	Sb	1 +	1	8.64	27.36
Br	2 +	3	36.00	Ta	1 +	1	7.89	28.11
Br	2 +	3	36.00	W	1 +	1	7.98	28.02
Br	2 +	3	36.00	Re	1 +	1	7.88	28.12
Br	2 +	3	36.00	Os	1 +	1	8.70	27.30
Br	2 +	3	36.00	Po	1 +	1	8.42	27.58
Br	3 +	4	47.30	Pd	2 +	2	19.43	27.87
Br	3 +	4	47.30	In	2 +	2	18.87	28.43
Br	3 +	4	47.30	I	2 +	2	19.13	28.17
Br	3 +	4	47.30	La	3 +	3	19.18	28.12

Br 3 +	4	47.30		Ce 3 +	3	20.20	27.10
Br 4 +	5	59.70		Xe 3 +	3	32.10	27.60
Br 4 +	5	59.70		Pb 3 +	3	31.94	27.76
Y 6 +	7	116.00		Br 6 +	6	88.60	27.40
Br 5 +	6	88.60		Mo 5 +	5	61.20	27.40
Pm 3 +	4	41.10		Kr 1 +	1	14.00	27.10
Sm 3 +	4	41.40		Kr 1 +	1	14.00	27.40
Dy 3 +	4	41.50		Kr 1 +	1	14.00	27.50
Pb 3 +	4	42.32		Kr 1 +	1	14.00	28.32
Kr 3 +	4	52.50		Kr 2 +	2	24.36	28.14
Rb 3 +	4	52.60		Kr 2 +	2	24.36	28.24
Kr 4 +	5	64.70		Kr 3 +	3	36.95	27.75
Kr 2 +	3	36.95		Cd 1 +	1	8.99	27.96
Kr 2 +	3	36.95		Sb 1 +	1	8.64	28.31
Kr 2 +	3	36.95		Te 1 +	1	9.01	27.94
Kr 2 +	3	36.95		Os 1 +	1	8.70	28.25
Kr 2 +	3	36.95		Ir 1 +	1	9.10	27.85
Kr 2 +	3	36.95		Pt 1 +	1	9.00	27.95
Kr 2 +	3	36.95		Au 1 +	1	9.23	27.73
Kr 3 +	4	52.50		Kr 2 +	2	24.36	28.14
Kr 3 +	4	52.50		Nb 3 +	3	25.04	27.46
Kr 3 +	4	52.50		Sb 3 +	3	25.30	27.20
Kr 3 +	4	52.50		Cs 2 +	2	25.10	27.40
Kr 3 +	4	52.50		Eu 3 +	3	24.90	27.60
Kr 3 +	4	52.50		Yb 3 +	3	25.03	27.47
Kr 4 +	5	64.70		Kr 3 +	3	36.95	27.75
Y 5 +	6	93.00		Kr 5 +	5	64.70	28.30
Kr 4 +	5	64.70		Cd 3 +	3	37.48	27.22
Kr 4 +	5	64.70		Te 4 +	4	37.41	27.29
Kr 4 +	5	64.70		Ce 4 +	4	36.76	27.94
Sr 6 +	7	106.00		Kr 6 +	6	78.50	27.50
Kr 5 +	6	78.50		Nb 5 +	5	50.55	27.95
Xe 2 +	3	32.10		Rb 1 +	1	4.18	27.92
Pb 2 +	3	31.94		Rb 1 +	1	4.18	27.76
Rb 2 +	3	40.00		Y 2 +	2	12.24	27.76
Mo 5 +	6	68.00		Rb 3 +	3	40.00	28.00

	Te 5 +	6	70.70	Sr 3 +	3	43.60	27.10
	Sr 3 +	4	57.00	Tc 3 +	3	29.54	27.46
	Sr 3 +	4	57.00	Tl 3 +	3	29.83	27.17
	Sr 4 +	5	71.60	Sr 3 +	3	43.60	28.00
5	Sr 4 +	5	71.60	Sb 4 +	4	44.20	27.40
	Sr 4 +	5	71.60	Gd 4 +	4	44.00	27.60
	Sr 4 +	5	71.60	Yb 4 +	4	43.70	27.90
	Zr 3 +	4	34.34	Y 1 +	1	6.38	27.96
	Ag 2 +	3	34.83	Y 1 +	1	6.38	28.45
10	Hg 2 +	3	34.20	Y 1 +	1	6.38	27.82
	Sn 3 +	4	40.73	Y 2 +	2	12.24	28.49
	Nd 3 +	4	40.41	Y 2 +	2	12.24	28.17
	Tb 3 +	4	39.80	Y 2 +	2	12.24	27.56
	Y 3 +	4	61.80	Zr 4 +	4	34.34	27.46
15	Y 3 +	4	61.80	Hf 4 +	4	33.33	28.47
	Y 3 +	4	61.80	Hg 3 +	3	34.20	27.60
	Y 4 +	5	77.00	La 4 +	4	49.95	27.05
	Y 6 +	7	116.00	Bi 6 +	6	88.30	27.70
	Zr 3 +	4	34.34	Zr 1 +	1	6.84	27.50
20	Ag 2 +	3	34.83	Zr 1 +	1	6.84	27.99
	Hg 2 +	3	34.20	Zr 1 +	1	6.84	27.36
	Sn 3 +	4	40.73	Zr 2 +	2	13.13	27.60
	Nd 3 +	4	40.41	Zr 2 +	2	13.13	27.28
	Pm 3 +	4	41.10	Zr 2 +	2	13.13	27.97
25	Sm 3 +	4	41.40	Zr 2 +	2	13.13	28.27
	Dy 3 +	4	41.50	Zr 2 +	2	13.13	28.37
	Nb 4 +	5	50.55	Zr 3 +	3	22.99	27.56
	Zr 3 +	4	34.34	Zr 1 +	1	6.84	27.50
	Zr 3 +	4	34.34	Nb 1 +	1	6.88	27.46
30	Zr 3 +	4	34.34	Mo 1 +	1	7.10	27.24
	Zr 3 +	4	34.34	Tc 1 +	1	7.28	27.06
	Zr 3 +	4	34.34	Gd 1 +	1	6.14	28.20
	Zr 3 +	4	34.34	Tb 1 +	1	5.85	28.49
	Zr 3 +	4	34.34	Dy 1 +	1	5.93	28.41
35	Zr 3 +	4	34.34	Ho 1 +	1	6.02	28.32
	Zr 3 +	4	34.34	Er 1 +	1	6.10	28.24

	Zr 3 +	4	34.34	Tm 1 +	1	6.18	28.16
	Zr 3 +	4	34.34	Yb 1 +	1	6.25	28.09
	Zr 3 +	4	34.34	Hf 1 +	1	6.60	27.74
	Zr 3 +	4	34.34	Tl 1 +	1	6.11	28.23
5	Zr 3 +	4	34.34	Bi 1 +	1	7.29	27.05
	Zr 3 +	4	34.34	Th 1 +	1	6.10	28.24
	Zr 3 +	4	34.34	Pa 1 +	1	5.90	28.44
	Zr 3 +	4	34.34	U 1 +	1	6.05	28.29
	Zr 3 +	4	34.34	Np 1 +	1	6.20	28.14
10	Zr 3 +	4	34.34	Pu 1 +	1	6.06	28.28
	Zr 3 +	4	34.34	Am 1 +	1	5.99	28.35
	Zr 3 +	4	34.34	Cm 1 +	1	6.02	28.32
	Zr 3 +	4	34.34	Bk 1 +	1	6.23	28.11
	Zr 3 +	4	34.34	Cf 1 +	1	6.30	28.04
15	Zr 3 +	4	34.34	Es 1 +	1	6.42	27.92
	Zr 4 +	5	81.50	In 4 +	4	54.00	27.50
	Ag 2 +	3	34.83	Nb 1 +	1	6.88	27.95
	Hg 2 +	3	34.20	Nb 1 +	1	6.88	27.32
	Sm 3 +	4	41.40	Nb 2 +	2	14.32	27.08
20	Eu 3 +	4	42.60	Nb 2 +	2	14.32	28.28
	Dy 3 +	4	41.50	Nb 2 +	2	14.32	27.18
	Ho 3 +	4	42.50	Nb 2 +	2	14.32	28.18
	Er 3 +	4	42.60	Nb 2 +	2	14.32	28.28
	Tm 3 +	4	42.70	Nb 2 +	2	14.32	28.38
25	Pb 3 +	4	42.32	Nb 2 +	2	14.32	28.00
	Nb 3 +	4	38.30	I 1 +	1	10.45	27.85
	Nb 3 +	4	38.30	Ba 2 +	2	10.00	28.30
	Nb 3 +	4	38.30	La 2 +	2	11.06	27.24
	Nb 3 +	4	38.30	Ce 2 +	2	10.85	27.45
30	Nb 3 +	4	38.30	Pr 2 +	2	10.55	27.75
	Nb 3 +	4	38.30	Nd 2 +	2	10.73	27.57
	Nb 3 +	4	38.30	Pm 2 +	2	10.90	27.40
	Nb 3 +	4	38.30	Sm 2 +	2	11.07	27.23
	Nb 3 +	4	38.30	Eu 2 +	2	11.24	27.06
35	Nb 3 +	4	38.30	Hg 1 +	1	10.44	27.86
	Nb 3 +	4	38.30	Rn 1 +	1	10.75	27.55

Nb 3 +	4	38.30		Ra 2 +	2	10.15	28.15
Nb 4 +	5	50.55		Nd 3 +	3	22.10	28.45
Nb 4 +	5	50.55		Pm 3 +	3	22.30	28.25
Nb 4 +	5	50.55		Sm 3 +	3	23.40	27.15
Nb 4 +	5	50.55		Dy 3 +	3	22.80	27.75
Nb 4 +	5	50.55		Ho 3 +	3	22.84	27.71
Nb 4 +	5	50.55		Er 3 +	3	22.74	27.81
Nb 4 +	5	50.55		Hf 3 +	3	23.30	27.25
Mo 7 +	8	153.00		Nb 7 +	7	125.00	28.00
Ag 2 +	3	34.83		Mo 1 +	1	7.10	27.73
Hg 2 +	3	34.20		Mo 1 +	1	7.10	27.10
Sb 3 +	4	44.20		Mo 2 +	2	16.15	28.05
Gd 3 +	4	44.00		Mo 2 +	2	16.15	27.85
Yb 3 +	4	43.70		Mo 2 +	2	16.15	27.55
Mo 3 +	4	46.40		Rh 2 +	2	18.08	28.32
Mo 3 +	4	46.40		In 2 +	2	18.87	27.53
Mo 3 +	4	46.40		Te 2 +	2	18.60	27.80
Mo 3 +	4	46.40		I 2 +	2	19.13	27.27
Mo 3 +	4	46.40		La 3 +	3	19.18	27.22
Mo 3 +	4	46.40		Pt 2 +	2	18.56	27.84
Mo 3 +	4	46.40		Hg 2 +	2	18.76	27.64
Mo 4 +	5	61.20		Pd 3 +	3	32.93	28.27
Mo 4 +	5	61.20		I 3 +	3	33.00	28.20
Mo 4 +	5	61.20		Hf 4 +	4	33.33	27.87
Bi 5 +	6	88.30		Mo 5 +	5	61.20	27.10
Mo 5 +	6	68.00		Sn 4 +	4	40.73	27.27
Mo 5 +	6	68.00		Nd 4 +	4	40.41	27.59
Mo 5 +	6	68.00		Tb 4 +	4	39.80	28.20
Ag 2 +	3	34.83		Tc 1 +	1	7.28	27.55
Eu 3 +	4	42.60		Tc 2 +	2	15.26	27.34
Ho 3 +	4	42.50		Tc 2 +	2	15.26	27.24
Er 3 +	4	42.60		Tc 2 +	2	15.26	27.34
Tm 3 +	4	42.70		Tc 2 +	2	15.26	27.44
Yb 3 +	4	43.70		Tc 2 +	2	15.26	28.44
Pb 3 +	4	42.32		Tc 2 +	2	15.26	27.06
Ag 2 +	3	34.83		Ru 1 +	1	7.37	27.46

	Sb 3 +	4	44.20	Ru 2 +	2	16.76	27.44
	Gd 3 +	4	44.00	Ru 2 +	2	16.76	27.24
	Lu 3 +	4	45.19	Ru 2 +	2	16.76	28.43
	Sb 4 +	5	56.00	Ru 3 +	3	28.47	27.53
5	Bi 4 +	5	56.00	Ru 3 +	3	28.47	27.53
	Ag 2 +	3	34.83	Rh 1 +	1	7.46	27.37
	Lu 3 +	4	45.19	Rh 2 +	2	18.08	27.11
	Bi 3 +	4	45.30	Rh 2 +	2	18.08	27.22
	Te 4 +	5	58.75	Rh 3 +	3	31.06	27.69
10	Rh 2 +	3	31.06	Cs 1 +	1	3.89	27.17
	Ce 3 +	4	36.76	Pd 1 +	1	8.34	28.42
	Pd 2 +	3	32.93	In 1 +	1	5.79	27.14
	Pd 2 +	3	32.93	Ba 1 +	1	5.21	27.72
	Pd 2 +	3	32.93	La 1 +	1	5.58	27.35
15	Pd 2 +	3	32.93	Ce 1 +	1	5.47	27.46
	Pd 2 +	3	32.93	Pr 1 +	1	5.42	27.51
	Pd 2 +	3	32.93	Nd 1 +	1	5.49	27.44
	Pd 2 +	3	32.93	Pm 1 +	1	5.55	27.38
	Pd 2 +	3	32.93	Sm 1 +	1	5.63	27.30
20	Pd 2 +	3	32.93	Eu 1 +	1	5.67	27.26
	Pd 2 +	3	32.93	Tb 1 +	1	5.85	27.08
	Pd 2 +	3	32.93	Dy 1 +	1	5.93	27.00
	Pd 2 +	3	32.93	Lu 1 +	1	5.43	27.50
	Pd 2 +	3	32.93	Ra 1 +	1	5.28	27.65
25	Pd 2 +	3	32.93	Ac 1 +	1	5.20	27.73
	Pd 2 +	3	32.93	Pa 1 +	1	5.90	27.03
	Ag 2 +	3	34.83	Ag 1 +	1	7.58	27.25
	La 3 +	4	49.95	Ag 2 +	2	21.49	28.46
	Ag 2 +	3	34.83	Ag 1 +	1	7.58	27.25
30	Ag 2 +	3	34.83	Sn 1 +	1	7.34	27.49
	Ag 2 +	3	34.83	Hf 1 +	1	6.60	28.23
	Ag 2 +	3	34.83	Pb 1 +	1	7.42	27.41
	Ag 2 +	3	34.83	Bi 1 +	1	7.29	27.54
	Ag 2 +	3	34.83	Es 1 +	1	6.42	28.41
35	Cd 2 +	3	37.48	Cd 1 +	1	8.99	28.49
	Te 3 +	4	37.41	Cd 1 +	1	8.99	28.42

	Ce 3 +	4	36.76	Cd 1 +	1	8.99	27.76
	Sb 3 +	4	44.20	Cd 2 +	2	16.91	27.29
	Gd 3 +	4	44.00	Cd 2 +	2	16.91	27.09
	Lu 3 +	4	45.19	Cd 2 +	2	16.91	28.28
5	Bi 3 +	4	45.30	Cd 2 +	2	16.91	28.39
	Cd 2 +	3	37.48	Cd 1 +	1	8.99	28.49
	Cd 2 +	3	37.48	Te 1 +	1	9.01	28.47
	Cd 2 +	3	37.48	I 1 +	1	10.45	27.03
	Cd 2 +	3	37.48	Ba 2 +	2	10.00	27.48
10	Cd 2 +	3	37.48	Ir 1 +	1	9.10	28.38
	Cd 2 +	3	37.48	Pt 1 +	1	9.00	28.48
	Cd 2 +	3	37.48	Au 1 +	1	9.23	28.25
	Cd 2 +	3	37.48	Hg 1 +	1	10.44	27.04
	Cd 2 +	3	37.48	Ra 2 +	2	10.15	27.33
15	I 2 +	3	33.00	In 1 +	1	5.79	27.21
	Hf 3 +	4	33.33	In 1 +	1	5.79	27.54
	Hg 2 +	3	34.20	In 1 +	1	5.79	28.41
	Sb 4 +	5	56.00	In 3 +	3	28.03	27.97
	Bi 4 +	5	56.00	In 3 +	3	28.03	27.97
20	In 3 +	4	54.00	Bi 3 +	3	25.56	28.44
	Eu 3 +	4	42.60	Sn 2 +	2	14.63	27.97
	Ho 3 +	4	42.50	Sn 2 +	2	14.63	27.87
	Er 3 +	4	42.60	Sn 2 +	2	14.63	27.97
	Tm 3 +	4	42.70	Sn 2 +	2	14.63	28.07
25	Pb 3 +	4	42.32	Sn 2 +	2	14.63	27.69
	Te 4 +	5	58.75	Sn 3 +	3	30.50	28.25
	Pb 4 +	5	68.80	Sn 4 +	4	40.73	28.07
	Sn 4 +	5	72.28	Sb 4 +	4	44.20	28.08
	Sn 4 +	5	72.28	Gd 4 +	4	44.00	28.28
30	Sn 4 +	5	72.28	Lu 4 +	4	45.19	27.09
	Ce 3 +	4	36.76	Sb 1 +	1	8.64	28.12
	Sb 3 +	4	44.20	Sb 2 +	2	16.53	27.67
	Gd 3 +	4	44.00	Sb 2 +	2	16.53	27.47
	Yb 3 +	4	43.70	Sb 2 +	2	16.53	27.17
35	Sb 3 +	4	44.20	Sb 2 +	2	16.53	27.67
	Sb 3 +	4	44.20	Bi 2 +	2	16.69	27.51

	Sb 4 +	5	56.00	Te 3 +	3	27.96	28.04
	Te 3 +	4	37.41	Te 1 +	1	9.01	28.40
	Ce 3 +	4	36.76	Te 1 +	1	9.01	27.75
	Bi 4 +	5	56.00	Te 3 +	3	27.96	28.04
5	Te 3 +	4	37.41	Te 1 +	1	9.01	28.40
	Te 3 +	4	37.41	Ba 2 +	2	10.00	27.41
	Te 3 +	4	37.41	Ir 1 +	1	9.10	28.31
	Te 3 +	4	37.41	Pt 1 +	1	9.00	28.41
	Te 3 +	4	37.41	Au 1 +	1	9.23	28.18
10	Te 3 +	4	37.41	Ra 2 +	2	10.15	27.26
	Te 5 +	6	70.70	Eu 4 +	4	42.60	28.10
	Te 5 +	6	70.70	Ho 4 +	4	42.50	28.20
	Te 5 +	6	70.70	Er 4 +	4	42.60	28.10
	Te 5 +	6	70.70	Tm 4 +	4	42.70	28.00
15	Te 5 +	6	70.70	Pb 4 +	4	42.32	28.38
	I 2 +	3	33.00	Ba 1 +	1	5.21	27.79
	I 2 +	3	33.00	La 1 +	1	5.58	27.42
	I 2 +	3	33.00	Ce 1 +	1	5.47	27.53
	I 2 +	3	33.00	Pr 1 +	1	5.42	27.58
20	I 2 +	3	33.00	Nd 1 +	1	5.49	27.51
	I 2 +	3	33.00	Pm 1 +	1	5.55	27.45
	I 2 +	3	33.00	Sm 1 +	1	5.63	27.37
	I 2 +	3	33.00	Eu 1 +	1	5.67	27.33
	I 2 +	3	33.00	Tb 1 +	1	5.85	27.15
25	I 2 +	3	33.00	Dy 1 +	1	5.93	27.07
	I 2 +	3	33.00	Lu 1 +	1	5.43	27.57
	I 2 +	3	33.00	Ra 1 +	1	5.28	27.72
	I 2 +	3	33.00	Ac 1 +	1	5.20	27.80
	I 2 +	3	33.00	Pa 1 +	1	5.90	27.10
30	I 2 +	3	33.00	Am 1 +	1	5.99	27.01
	Nd 3 +	4	40.41	Xe 1 +	1	12.13	28.28
	Tb 3 +	4	39.80	Xe 1 +	1	12.13	27.67
	Xe 2 +	3	32.10	Cs 1 +	1	3.89	28.21
	Pb 2 +	3	31.94	Cs 1 +	1	3.89	28.04
35	Hf 3 +	4	33.33	Ba 1 +	1	5.21	28.12
	Hf 3 +	4	33.33	La 1 +	1	5.58	27.75

	Pr 3 +	4	38.98	La 2 +	2	11.06	27.92
	La 3 +	4	49.95	Pr 3 +	3	21.62	28.33
	La 3 +	4	49.95	Nd 3 +	3	22.10	27.85
	La 3 +	4	49.95	Pm 3 +	3	22.30	27.65
5	La 3 +	4	49.95	Tb 3 +	3	21.91	28.04
	La 3 +	4	49.95	Dy 3 +	3	22.80	27.15
	La 3 +	4	49.95	Ho 3 +	3	22.84	27.11
	La 3 +	4	49.95	Er 3 +	3	22.74	27.21
	Hf 3 +	4	33.33	Ce 1 +	1	5.47	27.86
10	Pr 3 +	4	38.98	Ce 2 +	2	10.85	28.13
	Ce 3 +	4	36.76	Os 1 +	1	8.70	28.06
	Ce 3 +	4	36.76	Ir 1 +	1	9.10	27.66
	Ce 3 +	4	36.76	Pt 1 +	1	9.00	27.76
	Ce 3 +	4	36.76	Au 1 +	1	9.23	27.53
15	Ce 3 +	4	36.76	Po 1 +	1	8.42	28.34
	Hf 3 +	4	33.33	Pr 1 +	1	5.42	27.91
	Pr 3 +	4	38.98	Pr 2 +	2	10.55	28.43
	Pr 3 +	4	38.98	Pr 2 +	2	10.55	28.43
	Pr 3 +	4	38.98	Nd 2 +	2	10.73	28.25
20	Pr 3 +	4	38.98	Pm 2 +	2	10.90	28.08
	Pr 3 +	4	38.98	Sm 2 +	2	11.07	27.91
	Pr 3 +	4	38.98	Eu 2 +	2	11.24	27.74
	Pr 3 +	4	38.98	Tb 2 +	2	11.52	27.46
	Pr 3 +	4	38.98	Dy 2 +	2	11.67	27.31
25	Pr 3 +	4	38.98	Ho 2 +	2	11.80	27.18
	Pr 3 +	4	38.98	Er 2 +	2	11.93	27.05
	Pr 3 +	4	38.98	Rn 1 +	1	10.75	28.23
	Hf 3 +	4	33.33	Nd 1 +	1	5.49	27.84
	Nd 3 +	4	40.41	Gd 2 +	2	12.09	28.32
30	Nd 3 +	4	40.41	Er 2 +	2	11.93	28.48
	Nd 3 +	4	40.41	Tm 2 +	2	12.05	28.36
	Nd 3 +	4	40.41	Yb 2 +	2	12.18	28.23
	Pb 4 +	5	68.80	Nd 4 +	4	40.41	28.39
	Hf 3 +	4	33.33	Pm 1 +	1	5.55	27.78
35	Pm 3 +	4	41.10	Lu 2 +	2	13.90	27.20
	Pb 4 +	5	68.80	Pm 4 +	4	41.10	27.70

	Hf 3 +	4	33.33	Sm 1 +	1	5.63	27.70
	Sm 3 +	4	41.40	Lu 2 +	2	13.90	27.50
	Pb 4 +	5	68.80	Sm 4 +	4	41.40	27.40
	Hf 3 +	4	33.33	Eu 1 +	1	5.67	27.66
5	Eu 3 +	4	42.60	Hf 2 +	2	14.90	27.70
	Eu 3 +	4	42.60	Pb 2 +	2	15.03	27.57
	Hf 3 +	4	33.33	Gd 1 +	1	6.14	27.19
	Hg 2 +	3	34.20	Gd 1 +	1	6.14	28.06
	Tb 3 +	4	39.80	Gd 2 +	2	12.09	27.71
10	Gd 3 +	4	44.00	Bi 2 +	2	16.69	27.31
	Hf 3 +	4	33.33	Tb 1 +	1	5.85	27.48
	Hg 2 +	3	34.20	Tb 1 +	1	5.85	28.35
	Tb 3 +	4	39.80	Tb 2 +	2	11.52	28.28
	Tb 3 +	4	39.80	Tb 2 +	2	11.52	28.28
15	Tb 3 +	4	39.80	Dy 2 +	2	11.67	28.13
	Tb 3 +	4	39.80	Ho 2 +	2	11.80	28.00
	Tb 3 +	4	39.80	Er 2 +	2	11.93	27.87
	Tb 3 +	4	39.80	Tm 2 +	2	12.05	27.75
	Tb 3 +	4	39.80	Yb 2 +	2	12.18	27.62
20	Hf 3 +	4	33.33	Dy 1 +	1	5.93	27.40
	Hg 2 +	3	34.20	Dy 1 +	1	5.93	28.27
	Dy 3 +	4	41.50	Lu 2 +	2	13.90	27.60
	Pb 4 +	5	68.80	Dy 4 +	4	41.50	27.30
	Hf 3 +	4	33.33	Ho 1 +	1	6.02	27.31
25	Hg 2 +	3	34.20	Ho 1 +	1	6.02	28.18
	Ho 3 +	4	42.50	Hf 2 +	2	14.90	27.60
	Ho 3 +	4	42.50	Pb 2 +	2	15.03	27.47
	Hf 3 +	4	33.33	Er 1 +	1	6.10	27.23
	Hg 2 +	3	34.20	Er 1 +	1	6.10	28.10
30	Er 3 +	4	42.60	Hf 2 +	2	14.90	27.70
	Er 3 +	4	42.60	Pb 2 +	2	15.03	27.57
	Hf 3 +	4	33.33	Tm 1 +	1	6.18	27.15
	Hg 2 +	3	34.20	Tm 1 +	1	6.18	28.02
	Tm 3 +	4	42.70	Hf 2 +	2	14.90	27.80
35	Tm 3 +	4	42.70	Pb 2 +	2	15.03	27.67
	Hf 3 +	4	33.33	Yb 1 +	1	6.25	27.08

Hg 2 +	3	34.20	Yb 1 +	1	6.25	27.95
Yb 3 +	4	43.70	Bi 2 +	2	16.69	27.01
Hf 3 +	4	33.33	Lu 1 +	1	5.43	27.90
Pb 3 +	4	42.32	Lu 2 +	2	13.90	28.42
Lu 3 +	4	45.19	Bi 2 +	2	16.69	28.50
Hg 2 +	3	34.20	Hf 1 +	1	6.60	27.60
Pb 3 +	4	42.32	Hf 2 +	2	14.90	27.42
Hf 3 +	4	33.33	Tl 1 +	1	6.11	27.22
Hf 3 +	4	33.33	Ra 1 +	1	5.28	28.05
Hf 3 +	4	33.33	Ac 1 +	1	5.20	28.13
Hf 3 +	4	33.33	Th 1 +	1	6.10	27.23
Hf 3 +	4	33.33	Pa 1 +	1	5.90	27.43
Hf 3 +	4	33.33	U 1 +	1	6.05	27.28
Hf 3 +	4	33.33	Np 1 +	1	6.20	27.13
Hf 3 +	4	33.33	Pu 1 +	1	6.06	27.27
Hf 3 +	4	33.33	Am 1 +	1	5.99	27.34
Hf 3 +	4	33.33	Cm 1 +	1	6.02	27.31
Hf 3 +	4	33.33	Bk 1 +	1	6.23	27.10
Hf 3 +	4	33.33	Cf 1 +	1	6.30	27.03
Hg 2 +	3	34.20	Tl 1 +	1	6.11	28.09
Hg 2 +	3	34.20	Th 1 +	1	6.10	28.10
Hg 2 +	3	34.20	Pa 1 +	1	5.90	28.30
Hg 2 +	3	34.20	U 1 +	1	6.05	28.15
Hg 2 +	3	34.20	Np 1 +	1	6.20	28.00
Hg 2 +	3	34.20	Pu 1 +	1	6.06	28.14
Hg 2 +	3	34.20	Am 1 +	1	5.99	28.21
Hg 2 +	3	34.20	Cm 1 +	1	6.02	28.18
Hg 2 +	3	34.20	Bk 1 +	1	6.23	27.97
Hg 2 +	3	34.20	Cf 1 +	1	6.30	27.90
Hg 2 +	3	34.20	Es 1 +	1	6.42	27.78
Pb 3 +	4	42.32	Pb 2 +	2	15.03	27.29
Pb 3 +	4	42.32	Pb 2 +	2	15.03	27.29

n' = 16 (resonance shrinkage energy is given by $\frac{n}{2}$ 27.21 eV; with n = 16, the resonance shrinkage energy is 217.68)

Atom	n	nth Ion.	Atom	n	nth Ion.	Energy

	Oxidized		Ionization Energy (eV)	Reduced		Ionization Energy (eV)	Hole (eV)
	Ne 7 +	8	239.09	He 1 +	1	24.59	214.50
5	Al 6 +	7	241.43	He 1 +	1	24.59	216.84
	Mg 6 +	7	224.94	Li 1 +	1	5.39	219.55
	P 5 +	6	220.43	Li 1 +	1	5.39	215.04
	B 4 +	5	340.22	Li 3 +	3	122.45	217.77
	Mg 6 +	7	224.94	Be 1 +	1	9.32	215.62
10	Ne 7 +	8	239.09	Be 2 +	2	18.21	220.88
	Mg 6 +	7	224.94	B 1 +	1	8.30	216.64
	Al 6 +	7	241.43	B 2 +	2	25.15	216.28
	B 3 +	4	259.37	Ne 2 +	2	40.96	218.41
	B 3 +	4	259.37	Si 4 +	4	45.14	214.23
15	B 3 +	4	259.37	Cl 3 +	3	39.61	219.76
	B 3 +	4	259.37	Ar 3 +	3	40.74	218.63
	B 3 +	4	259.37	Ti 4 +	4	43.27	216.10
	B 3 +	4	259.37	Zn 3 +	3	39.72	219.65
	B 3 +	4	259.37	Se 4 +	4	42.94	216.42
20	B 3 +	4	259.37	Rb 3 +	3	40.00	219.37
	B 3 +	4	259.37	Sr 3 +	3	43.60	215.77
	B 3 +	4	259.37	Sn 4 +	4	40.73	218.63
	B 3 +	4	259.37	Sb 4 +	4	44.20	215.17
	B 3 +	4	259.37	Pr 4 +	4	38.98	220.39
25	B 3 +	4	259.37	Nd 4 +	4	40.41	218.96
	B 3 +	4	259.37	Pm 4 +	4	41.10	218.27
	B 3 +	4	259.37	Sm 4 +	4	41.40	217.97
	B 3 +	4	259.37	Eu 4 +	4	42.60	216.77
	B 3 +	4	259.37	Gd 4 +	4	44.00	215.37
30	B 3 +	4	259.37	Tb 4 +	4	39.80	219.57
	B 3 +	4	259.37	Dy 4 +	4	41.50	217.87
	B 3 +	4	259.37	Ho 4 +	4	42.50	216.87
	B 3 +	4	259.37	Er 4 +	4	42.60	216.77
	B 3 +	4	259.37	Tm 4 +	4	42.70	216.67
35	B 3 +	4	259.37	Yb 4 +	4	43.70	215.67
	B 3 +	4	259.37	Lu 4 +	4	45.19	214.18

B 3 +	4	259.37	Pb 4 +	4	42.32	217.05
B 3 +	4	259.37	Bi 4 +	4	45.30	214.07
B 4 +	5	340.22	Ne 5 +	5	126.21	214.01
B 4 +	5	340.22	Al 4 +	4	119.99	220.23
B 4 +	5	340.22	Ar 7 +	7	124.32	215.90
B 4 +	5	340.22	Ti 6 +	6	119.36	220.86
B 4 +	5	340.22	Mn 7 +	7	119.27	220.95
B 4 +	5	340.22	Fe 7 +	7	125.00	215.22
B 4 +	5	340.22	Kr 8 +	8	126.00	214.22
B 4 +	5	340.22	Sr 8 +	8	122.30	217.92
B 4 +	5	340.22	Nb 7 +	7	125.00	215.22
Ne 7 +	8	239.09	C 2 +	2	24.38	214.71
Al 6 +	7	241.43	C 2 +	2	24.38	217.05
Na 7 +	8	264.18	C 3 +	3	47.89	216.29
Mg 7 +	8	265.90	C 3 +	3	47.89	218.01
P 6 +	7	263.22	C 3 +	3	47.89	215.33
Al 7 +	8	284.59	C 4 +	4	64.49	220.10
S 6 +	7	280.93	C 4 +	4	64.49	216.44
C 4 +	5	392.08	Na 6 +	6	172.15	219.93
C 4 +	5	392.08	V 8 +	8	173.70	218.38
C 4 +	5	392.08	Zn 8 +	8	174.00	218.08
Si 6 +	7	246.52	N 2 +	2	29.60	216.92
Na 7 +	8	264.18	N 3 +	3	47.45	216.73
Mg 7 +	8	265.90	N 3 +	3	47.45	218.45
P 6 +	7	263.22	N 3 +	3	47.45	215.77
S 7 +	8	328.23	O 5 +	5	113.90	214.33
F 7 +	8	953.89	O 7 +	7	739.32	214.57
S 6 +	7	280.93	F 3 +	3	62.71	218.22
Si 7 +	8	303.17	F 4 +	4	87.14	216.03
Ne 7 +	8	239.09	Ne 1 +	1	21.56	217.53
Al 6 +	7	241.43	Ne 1 +	1	21.56	219.87
S 6 +	7	280.93	Ne 3 +	3	63.45	217.48
Ne 7 +	8	239.09	Ne 1 +	1	21.56	217.53
Ne 7 +	8	239.09	Al 2 +	2	18.83	220.26
Ne 7 +	8	239.09	P 2 +	2	19.73	219.36
Ne 7 +	8	239.09	S 2 +	2	23.33	215.76

Ne 7 +	8	239.09	Cl 2 +	2	23.81	215.28
Ne 7 +	8	239.09	Sc 3 +	3	24.76	214.33
Ne 7 +	8	239.09	Ni 2 +	2	18.17	220.92
Ne 7 +	8	239.09	Cu 2 +	2	20.29	218.80
Ne 7 +	8	239.09	Ga 2 +	2	20.51	218.58
Ne 7 +	8	239.09	As 2 +	2	18.63	220.46
Ne 7 +	8	239.09	Se 2 +	2	21.19	217.90
Ne 7 +	8	239.09	Br 2 +	2	21.80	217.29
Ne 7 +	8	239.09	Kr 2 +	2	24.36	214.73
Ne 7 +	8	239.09	Y 3 +	3	20.52	218.57
Ne 7 +	8	239.09	Zr 3 +	3	22.99	216.10
Ne 7 +	8	239.09	Nb 3 +	3	25.04	214.05
Ne 7 +	8	239.09	Pd 2 +	2	19.43	219.66
Ne 7 +	8	239.09	Ag 2 +	2	21.49	217.60
Ne 7 +	8	239.09	In 2 +	2	18.87	220.22
Ne 7 +	8	239.09	Te 2 +	2	18.60	220.49
Ne 7 +	8	239.09	I 2 +	2	19.13	219.96
Ne 7 +	8	239.09	Xe 2 +	2	21.21	217.88
Ne 7 +	8	239.09	La 3 +	3	19.18	219.91
Ne 7 +	8	239.09	Ce 3 +	3	20.20	218.89
Ne 7 +	8	239.09	Pr 3 +	3	21.62	217.47
Ne 7 +	8	239.09	Nd 3 +	3	22.10	216.99
Ne 7 +	8	239.09	Pm 3 +	3	22.30	216.79
Ne 7 +	8	239.09	Sm 3 +	3	23.40	215.69
Ne 7 +	8	239.09	Eu 3 +	3	24.90	214.19
Ne 7 +	8	239.09	Gd 3 +	3	20.63	218.46
Ne 7 +	8	239.09	Tb 3 +	3	21.91	217.18
Ne 7 +	8	239.09	Dy 3 +	3	22.80	216.29
Ne 7 +	8	239.09	Ho 3 +	3	22.84	216.25
Ne 7 +	8	239.09	Er 3 +	3	22.74	216.35
Ne 7 +	8	239.09	Tm 3 +	3	23.68	215.41
Ne 7 +	8	239.09	Yb 3 +	3	25.03	214.06
Ne 7 +	8	239.09	Lu 3 +	3	20.96	218.13
Ne 7 +	8	239.09	Hf 3 +	3	23.30	215.79
Ne 7 +	8	239.09	Pt 2 +	2	18.56	220.53
Ne 7 +	8	239.09	Au 2 +	2	20.50	218.59

Ne 7 +	8	239.09	
Ne 7 +	8	239.09	
Mg 6 +	7	224.94	
P 5 +	6	220.43	
Na 7 +	8	264.18	
Mg 7 +	8	265.90	
P 6 +	7	263.22	
Na 7 +	8	264.18	
Na 7 +	8	264.18	
Na 7 +	8	264.18	
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Na 7 +	8	264.18	
Na 7 +	8	264.18	
Na 7 +	8	264.18	
Na 7 +	8	264.18	
Mg 6 +	7	224.94	
S 7 +	8	328.23	
Mg 6 +	7	224.94	
Mg 6 +	7	224.94	
Mg 6 +	7	224.94	
Mg 6 +	7	224.94	
Mg 6 +	7	224.94	
Mg 6 +	7	224.94	
Mg 6 +	7	224.94	
Hg 2 +	2	18.76	220.33
Tl 2 +	2	20.43	218.66
Na 1 +	1	5.14	219.80
Na 1 +	1	5.14	215.29
Na 2 +	2	47.29	216.89
Na 2 +	2	47.29	218.61
Na 2 +	2	47.29	215.93
Na 2 +	2	47.29	216.89
Si 4 +	4	45.14	219.04
S 4 +	4	47.30	216.88
K 3 +	3	45.72	218.46
Ti 4 +	4	43.27	220.91
V 4 +	4	46.71	217.47
Cr 4 +	4	49.10	215.08
Ge 4 +	4	45.71	218.47
As 4 +	4	50.13	214.05
Br 4 +	4	47.30	216.88
Sr 3 +	3	43.60	220.58
Mo 4 +	4	46.40	217.78
Sb 4 +	4	44.20	219.98
La 4 +	4	49.95	214.23
Gd 4 +	4	44.00	220.18
Yb 4 +	4	43.70	220.48
Lu 4 +	4	45.19	218.99
Bi 4 +	4	45.30	218.88
Mg 1 +	1	7.65	217.29
Mg 4 +	4	109.24	218.99
Mg 1 +	1	7.65	217.29
Al 1 +	1	5.99	218.95
Si 1 +	1	8.15	216.79
P 1 +	1	10.49	214.45
S 1 +	1	10.36	214.58
K 1 +	1	4.34	220.60
Ca 1 +	1	6.11	218.83
Sc 1 +	1	6.54	218.40
Ti 1 +	1	6.82	218.12

Mg 6 +	7	224.94	V 1 +	1	6.74	218.20
Mg 6 +	7	224.94	Cr 1 +	1	6.77	218.17
Mg 6 +	7	224.94	Mn 1 +	1	7.43	217.51
Mg 6 +	7	224.94	Fe 1 +	1	7.87	217.07
Mg 6 +	7	224.94	Co 1 +	1	7.86	217.08
Mg 6 +	7	224.94	Ni 1 +	1	7.64	217.31
Mg 6 +	7	224.94	Cu 1 +	1	7.73	217.21
Mg 6 +	7	224.94	Zn 1 +	1	9.39	215.55
Mg 6 +	7	224.94	Ga 1 +	1	6.00	218.94
Mg 6 +	7	224.94	Ge 1 +	1	7.90	217.04
Mg 6 +	7	224.94	As 1 +	1	9.81	215.13
Mg 6 +	7	224.94	Se 1 +	1	9.75	215.19
Mg 6 +	7	224.94	Rb 1 +	1	4.18	220.76
Mg 6 +	7	224.94	Sr 1 +	1	5.70	219.24
Mg 6 +	7	224.94	Y 1 +	1	6.38	218.56
Mg 6 +	7	224.94	Zr 1 +	1	6.84	218.10
Mg 6 +	7	224.94	Nb 1 +	1	6.88	218.06
Mg 6 +	7	224.94	Mo 1 +	1	7.10	217.84
Mg 6 +	7	224.94	Tc 1 +	1	7.28	217.66
Mg 6 +	7	224.94	Ru 1 +	1	7.37	217.57
Mg 6 +	7	224.94	Rh 1 +	1	7.46	217.48
Mg 6 +	7	224.94	Pd 1 +	1	8.34	216.60
Mg 6 +	7	224.94	Ag 1 +	1	7.58	217.36
Mg 6 +	7	224.94	Cd 1 +	1	8.99	215.95
Mg 6 +	7	224.94	In 1 +	1	5.79	219.15
Mg 6 +	7	224.94	Sn 1 +	1	7.34	217.60
Mg 6 +	7	224.94	Sb 1 +	1	8.64	216.30
Mg 6 +	7	224.94	Te 1 +	1	9.01	215.93
Mg 6 +	7	224.94	I 1 +	1	10.45	214.49
Mg 6 +	7	224.94	Ba 1 +	1	5.21	219.73
Mg 6 +	7	224.94	Ba 2 +	2	10.00	214.94
Mg 6 +	7	224.94	La 1 +	1	5.58	219.36
Mg 6 +	7	224.94	Ce 1 +	1	5.47	219.47
Mg 6 +	7	224.94	Ce 2 +	2	10.85	214.09
Mg 6 +	7	224.94	Pr 1 +	1	5.42	219.52
Mg 6 +	7	224.94	Pr 2 +	2	10.55	214.39

	Mg 6 +	7	224.94	Nd 1 +	1	5.49	219.45
	Mg 6 +	7	224.94	Nd 2 +	2	10.73	214.21
	Mg 6 +	7	224.94	Pm 1 +	1	5.55	219.39
	Mg 6 +	7	224.94	Pm 2 +	2	10.90	214.04
5	Mg 6 +	7	224.94	Sm 1 +	1	5.63	219.31
	Mg 6 +	7	224.94	Eu 1 +	1	5.67	219.27
	Mg 6 +	7	224.94	Gd 1 +	1	6.14	218.80
	Mg 6 +	7	224.94	Tb 1 +	1	5.85	219.09
	Mg 6 +	7	224.94	Dy 1 +	1	5.93	219.01
10	Mg 6 +	7	224.94	Ho 1 +	1	6.02	218.92
	Mg 6 +	7	224.94	Er 1 +	1	6.10	218.84
	Mg 6 +	7	224.94	Tm 1 +	1	6.18	218.76
	Mg 6 +	7	224.94	Yb 1 +	1	6.25	218.69
	Mg 6 +	7	224.94	Lu 1 +	1	5.43	219.51
15	Mg 6 +	7	224.94	Hf 1 +	1	6.60	218.34
	Mg 6 +	7	224.94	Ta 1 +	1	7.89	217.05
	Mg 6 +	7	224.94	W 1 +	1	7.98	216.96
	Mg 6 +	7	224.94	Re 1 +	1	7.88	217.06
	Mg 6 +	7	224.94	Os 1 +	1	8.70	216.24
20	Mg 6 +	7	224.94	Ir 1 +	1	9.10	215.84
	Mg 6 +	7	224.94	Pt 1 +	1	9.00	215.94
	Mg 6 +	7	224.94	Au 1 +	1	9.23	215.71
	Mg 6 +	7	224.94	Hg 1 +	1	10.44	214.50
	Mg 6 +	7	224.94	Tl 1 +	1	6.11	218.83
25	Mg 6 +	7	224.94	Pb 1 +	1	7.42	217.52
	Mg 6 +	7	224.94	Bi 1 +	1	7.29	217.65
	Mg 6 +	7	224.94	Po 1 +	1	8.42	216.52
	Mg 6 +	7	224.94	Rn 1 +	1	10.75	214.19
	Mg 6 +	7	224.94	Ra 1 +	1	5.28	219.66
30	Mg 6 +	7	224.94	Ra 2 +	2	10.15	214.79
	Mg 6 +	7	224.94	Ac 1 +	1	5.20	219.74
	Mg 6 +	7	224.94	Th 1 +	1	6.10	218.84
	Mg 6 +	7	224.94	Pa 1 +	1	5.90	219.04
	Mg 6 +	7	224.94	U 1 +	1	6.05	218.89
35	Mg 6 +	7	224.94	Np 1 +	1	6.20	218.74
	Mg 6 +	7	224.94	Pu 1 +	1	6.06	218.88

Mg	6 +	7	224.94	Am	1 +	1	5.99	218.95
Mg	6 +	7	224.94	Cm	1 +	1	6.02	218.92
Mg	6 +	7	224.94	Bk	1 +	1	6.23	218.71
Mg	6 +	7	224.94	Cf	1 +	1	6.30	218.64
Mg	6 +	7	224.94	Es	1 +	1	6.42	218.52
Mg	7 +	8	265.90	Si	4 +	4	45.14	220.76
Mg	7 +	8	265.90	P	4 +	4	51.37	214.53
Mg	7 +	8	265.90	S	4 +	4	47.30	218.60
Mg	7 +	8	265.90	K	3 +	3	45.72	220.18
Mg	7 +	8	265.90	Ca	3 +	3	50.91	214.99
Mg	7 +	8	265.90	V	4 +	4	46.71	219.19
Mg	7 +	8	265.90	Cr	4 +	4	49.10	216.80
Mg	7 +	8	265.90	Mn	4 +	4	51.20	214.70
Mg	7 +	8	265.90	Co	4 +	4	51.30	214.60
Mg	7 +	8	265.90	Ge	4 +	4	45.71	220.19
Mg	7 +	8	265.90	As	4 +	4	50.13	215.77
Mg	7 +	8	265.90	Br	4 +	4	47.30	218.60
Mg	7 +	8	265.90	Nb	5 +	5	50.55	215.35
Mg	7 +	8	265.90	Mo	4 +	4	46.40	219.50
Mg	7 +	8	265.90	La	4 +	4	49.95	215.95
Mg	7 +	8	265.90	Lu	4 +	4	45.19	220.71
Mg	7 +	8	265.90	Bi	4 +	4	45.30	220.60
P	5 +	6	220.43	Al	1 +	1	5.99	214.44
Si	6 +	7	246.52	Al	3 +	3	28.45	218.07
Al	6 +	7	241.43	S	2 +	2	23.33	218.10
Al	6 +	7	241.43	Cl	2 +	2	23.81	217.62
Al	6 +	7	241.43	Sc	3 +	3	24.76	216.67
Al	6 +	7	241.43	Ga	2 +	2	20.51	220.92
Al	6 +	7	241.43	Se	2 +	2	21.19	220.24
Al	6 +	7	241.43	Br	2 +	2	21.80	219.63
Al	6 +	7	241.43	Kr	2 +	2	24.36	217.07
Al	6 +	7	241.43	Rb	2 +	2	27.28	214.15
Al	6 +	7	241.43	Y	3 +	3	20.52	220.91
Al	6 +	7	241.43	Zr	3 +	3	22.99	218.44
Al	6 +	7	241.43	Nb	3 +	3	25.04	216.39
Al	6 +	7	241.43	Mo	3 +	3	27.16	214.27

Al 6 +	7	241.43	
Al 6 +	7	241.43	
Al 6 +	7	241.43	
Al 6 +	7	241.43	
Al 6 +	7	241.43	
Al 6 +	7	241.43	
Al 6 +	7	241.43	
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Al 6 +	7	241.43	
Al 6 +	7	241.43	
Al 6 +	7	241.43	
Al 6 +	7	241.43	
Al 6 +	7	241.43	
Al 7 +	8	284.59	
Al 7 +	8	284.59	
Al 7 +	8	284.59	
Al 7 +	8	284.59	
Al 7 +	8	284.59	
Al 7 +	8	284.59	
Al 7 +	8	284.59	
Al 7 +	8	284.59	
Al 7 +	8	284.59	
P 6 +	7	263.22	
Si 6 +	7	246.52	
Si 6 +	7	246.52	
Si 6 +	7	246.52	
Si 6 +	7	246.52	
Ag 2 +	2	21.49	219.94
Sb 3 +	3	25.30	216.13
Xe 2 +	2	21.21	220.22
Cs 2 +	2	25.10	216.33
Pr 3 +	3	21.62	219.81
Nd 3 +	3	22.10	219.33
Pm 3 +	3	22.30	219.13
Sm 3 +	3	23.40	218.03
Eu 3 +	3	24.90	216.53
Gd 3 +	3	20.63	220.80
Tb 3 +	3	21.91	219.52
Dy 3 +	3	22.80	218.63
Ho 3 +	3	22.84	218.59
Er 3 +	3	22.74	218.69
Tm 3 +	3	23.68	217.75
Yb 3 +	3	25.03	216.40
Lu 3 +	3	20.96	220.47
Hf 3 +	3	23.30	218.13
Au 2 +	2	20.50	220.93
Bi 3 +	3	25.56	215.87
P 5 +	5	65.02	219.57
Cl 5 +	5	67.80	216.79
Ca 4 +	4	67.10	217.49
V 5 +	5	65.23	219.36
Cr 5 +	5	69.30	215.29
Ga 4 +	4	64.00	220.59
As 5 +	5	63.63	220.96
Se 5 +	5	68.30	216.29
Kr 5 +	5	64.70	219.89
Mo 6 +	6	68.00	216.59
Pb 5 +	5	68.80	215.79
Si 4 +	4	45.14	218.08
P 3 +	3	30.18	216.34
Ar 2 +	2	27.63	218.89
K 2 +	2	31.63	214.90
Ti 3 +	3	27.49	219.03

Si	6 +	7	246.52	V	3 +	3	29.31	217.21
Si	6 +	7	246.52	Cr	3 +	3	30.96	215.56
Si	6 +	7	246.52	Fe	3 +	3	30.65	215.87
Si	6 +	7	246.52	Ga	3 +	3	30.71	215.81
Si	6 +	7	246.52	As	3 +	3	28.35	218.17
Si	6 +	7	246.52	Se	3 +	3	30.82	215.70
Si	6 +	7	246.52	Rb	2 +	2	27.28	219.24
Si	6 +	7	246.52	Mo	3 +	3	27.16	219.36
Si	6 +	7	246.52	Tc	3 +	3	29.54	216.98
Si	6 +	7	246.52	Ru	3 +	3	28.47	218.05
Si	6 +	7	246.52	Rh	3 +	3	31.06	215.46
Si	6 +	7	246.52	In	3 +	3	28.03	218.49
Si	6 +	7	246.52	Sn	3 +	3	30.50	216.02
Si	6 +	7	246.52	Te	3 +	3	27.96	218.56
Si	6 +	7	246.52	Xe	3 +	3	32.10	214.42
Si	6 +	7	246.52	Tl	3 +	3	29.83	216.69
Si	6 +	7	246.52	Pb	3 +	3	31.94	214.58
Si	6 +	7	246.52	Bi	3 +	3	25.56	220.96
Si	7 +	8	303.17	S	6 +	6	88.05	215.12
Si	7 +	8	303.17	K	5 +	5	82.66	220.51
Si	7 +	8	303.17	Ca	5 +	5	84.41	218.76
Si	7 +	8	303.17	Zn	5 +	5	82.60	220.57
Si	7 +	8	303.17	Br	6 +	6	88.60	214.57
Si	7 +	8	303.17	Rb	6 +	6	84.40	218.77
Si	7 +	8	303.17	Bi	6 +	6	88.30	214.87
S	6 +	7	280.93	P	5 +	5	65.02	215.91
P	5 +	6	220.43	K	1 +	1	4.34	216.09
P	5 +	6	220.43	Ca	1 +	1	6.11	214.32
P	5 +	6	220.43	Ga	1 +	1	6.00	214.43
P	5 +	6	220.43	Rb	1 +	1	4.18	216.25
P	5 +	6	220.43	Sr	1 +	1	5.70	214.73
P	5 +	6	220.43	Y	1 +	1	6.38	214.05
P	5 +	6	220.43	In	1 +	1	5.79	214.64
P	5 +	6	220.43	Cs	1 +	1	3.89	216.54
P	5 +	6	220.43	Ba	1 +	1	5.21	215.22
P	5 +	6	220.43	La	1 +	1	5.58	214.85

P	5+	6	220.43	Ce	1+	1	5.47	214.96
P	5+	6	220.43	Pr	1+	1	5.42	215.01
P	5+	6	220.43	Nd	1+	1	5.49	214.94
P	5+	6	220.43	Pm	1+	1	5.55	214.88
P	5+	6	220.43	Sm	1+	1	5.63	214.80
P	5+	6	220.43	Eu	1+	1	5.67	214.76
P	5+	6	220.43	Gd	1+	1	6.14	214.29
P	5+	6	220.43	Tb	1+	1	5.85	214.58
P	5+	6	220.43	Dy	1+	1	5.93	214.50
P	5+	6	220.43	Ho	1+	1	6.02	214.41
P	5+	6	220.43	Er	1+	1	6.10	214.33
P	5+	6	220.43	Tm	1+	1	6.18	214.25
P	5+	6	220.43	Yb	1+	1	6.25	214.18
P	5+	6	220.43	Lu	1+	1	5.43	215.00
P	5+	6	220.43	Tl	1+	1	6.11	214.32
P	5+	6	220.43	Ra	1+	1	5.28	215.15
P	5+	6	220.43	Ac	1+	1	5.20	215.23
P	5+	6	220.43	Th	1+	1	6.10	214.33
P	5+	6	220.43	Pa	1+	1	5.90	214.53
P	5+	6	220.43	U	1+	1	6.05	214.38
P	5+	6	220.43	Np	1+	1	6.20	214.23
P	5+	6	220.43	Pu	1+	1	6.06	214.37
P	5+	6	220.43	Am	1+	1	5.99	214.44
P	5+	6	220.43	Cm	1+	1	6.02	214.41
P	5+	6	220.43	Bk	1+	1	6.23	214.20
P	5+	6	220.43	Cf	1+	1	6.30	214.13
P	5+	6	220.43	Es	1+	1	6.42	214.01
P	6+	7	263.22	S	4+	4	47.30	215.92
P	6+	7	263.22	K	3+	3	45.72	217.50
P	6+	7	263.22	Ti	4+	4	43.27	219.95
P	6+	7	263.22	V	4+	4	46.71	216.51
P	6+	7	263.22	Cr	4+	4	49.10	214.12
P	6+	7	263.22	Ge	4+	4	45.71	217.51
P	6+	7	263.22	Se	4+	4	42.94	220.28
P	6+	7	263.22	Br	4+	4	47.30	215.92
P	6+	7	263.22	Sr	3+	3	43.60	219.62

P 6 +	7	263.22	
P 6 +	7	263.22	
P 6 +	7	263.22	
P 6 +	7	263.22	
P 6 +	7	263.22	
P 6 +	7	263.22	
P 6 +	7	263.22	
P 6 +	7	263.22	
P 6 +	7	263.22	
P 7 +	8	309.41	
P 7 +	8	309.41	
P 7 +	8	309.41	
P 7 +	8	309.41	
P 7 +	8	309.41	
P 7 +	8	309.41	
P 7 +	8	309.41	
P 7 +	8	309.41	
S 6 +	7	280.93	
S 6 +	7	280.93	
S 6 +	7	280.93	
S 6 +	7	280.93	
S 6 +	7	280.93	
S 6 +	7	280.93	
S 6 +	7	280.93	
S 7 +	8	328.23	
S 7 +	8	328.23	
S 7 +	8	328.23	
S 7 +	8	328.23	
S 7 +	8	328.23	
S 7 +	8	328.23	
S 7 +	8	328.23	
Cl 7 +	8	348.28	
Cl 7 +	8	348.28	
Cl 7 +	8	348.28	
Mo 4 +	4	46.40	216.82
Sb 4 +	4	44.20	219.02
Eu 4 +	4	42.60	220.62
Gd 4 +	4	44.00	219.22
Ho 4 +	4	42.50	220.72
Er 4 +	4	42.60	220.62
Tm 4 +	4	42.70	220.52
Yb 4 +	4	43.70	219.52
Lu 4 +	4	45.19	218.03
Pb 4 +	4	42.32	220.90
Bi 4 +	4	45.30	217.92
Ar 6 +	6	91.01	218.40
Sc 5 +	5	91.66	217.75
Cr 6 +	6	90.56	218.85
Mn 6 +	6	95.00	214.41
Ge 5 +	5	93.50	215.91
Br 6 +	6	88.60	220.81
Sr 6 +	6	90.80	218.61
Y 6 +	6	93.00	216.41
K 4 +	4	60.91	220.02
V 5 +	5	65.23	215.70
Ga 4 +	4	64.00	216.93
As 5 +	5	63.63	217.30
Kr 5 +	5	64.70	216.23
Y 4 +	4	61.80	219.13
Mo 5 +	5	61.20	219.73
Cl 7 +	7	114.19	214.04
Ca 6 +	6	108.78	219.45
Sc 6 +	6	111.10	217.13
Ni 6 +	6	108.00	220.23
Zn 6 +	6	108.00	220.23
Kr 7 +	7	111.00	217.23
Sb 6 +	6	108.00	220.23
Ca 7 +	7	127.70	220.58
V 6 +	6	128.12	220.16
Co 7 +	7	129.00	219.28

Cl 7 +	8	348.28	Ni 7 +	7	133.00	215.28
Cl 7 +	8	348.28	Zn 7 +	7	134.00	214.28
Cl 7 +	8	348.28	As 6 +	6	127.60	220.68
Cl 7 +	8	348.28	Y 8 +	8	129.00	219.28

n = 54 (resonance shrinkage energy is given by $\frac{n}{2}$ 27.21 eV; with n= 54, the resonance shrinkage energy is 734.67)

Atom Oxidized	n	nth Ionization Energy (eV)	Atom Reduced	n	nth Ionization Energy (eV)	Energy Hole (eV)
O 6 +	7	739.32	Li 1 +	1	5.39	733.92
F 7 +	8	953.89	Be 4 +	4	217.71	736.17
O 6 +	7	739.32	B 1 +	1	8.30	731.02
O 7 +	8	871.39	O 6 +	6	138.12	733.27
O 6 +	7	739.32	Na 1 +	1	5.14	734.18
O 6 +	7	739.32	Mg 1 +	1	7.65	731.67
O 6 +	7	739.32	Al 1 +	1	5.99	733.33
O 6 +	7	739.32	Si 1 +	1	8.15	731.16
O 6 +	7	739.32	K 1 +	1	4.34	734.97
O 6 +	7	739.32	Ca 1 +	1	6.11	733.20
O 6 +	7	739.32	Sc 1 +	1	6.54	732.78
O 6 +	7	739.32	Ti 1 +	1	6.82	732.49
O 6 +	7	739.32	V 1 +	1	6.74	732.58
O 6 +	7	739.32	Cr 1 +	1	6.77	732.55
O 6 +	7	739.32	Mn 1 +	1	7.43	731.88
O 6 +	7	739.32	Fe 1 +	1	7.87	731.45
O 6 +	7	739.32	Co 1 +	1	7.86	731.46
O 6 +	7	739.32	Ni 1 +	1	7.64	731.68
O 6 +	7	739.32	Cu 1 +	1	7.73	731.59
O 6 +	7	739.32	Ga 1 +	1	6.00	733.32
O 6 +	7	739.32	Ge 1 +	1	7.90	731.42
O 6 +	7	739.32	Rb 1 +	1	4.18	735.14
O 6 +	7	739.32	Sr 1 +	1	5.70	733.62
O 6 +	7	739.32	Y 1 +	1	6.38	732.93
O 6 +	7	739.32	Zr 1 +	1	6.84	732.47

	O 6+	7	739.32	Nb 1 +	1	6.88	732.43
	O 6+	7	739.32	Mo 1 +	1	7.10	732.22
	O 6+	7	739.32	Tc 1 +	1	7.28	732.03
	O 6+	7	739.32	Ru 1 +	1	7.37	731.95
5	O 6+	7	739.32	Rh 1 +	1	7.46	731.85
	O 6+	7	739.32	Pd 1 +	1	8.34	730.97
	O 6+	7	739.32	Ag 1 +	1	7.58	731.74
	O 6+	7	739.32	Cd 1 +	1	8.99	730.32
	O 6+	7	739.32	In 1 +	1	5.79	733.53
10	O 6+	7	739.32	Sn 1 +	1	7.34	731.97
	O 6+	7	739.32	Sb 1 +	1	8.64	730.67
	O 6+	7	739.32	Te 1 +	1	9.01	730.31
	O 6+	7	739.32	Cs 1 +	1	3.89	735.42
	O 6+	7	739.32	Ba 1 +	1	5.21	734.10
15	O 6+	7	739.32	La 1 +	1	5.58	733.74
	O 6+	7	739.32	Ce 1 +	1	5.47	733.85
	O 6+	7	739.32	Pr 1 +	1	5.42	733.89
	O 6+	7	739.32	Nd 1 +	1	5.49	733.83
	O 6+	7	739.32	Pm 1 +	1	5.55	733.76
20	O 6+	7	739.32	Sm 1 +	1	5.63	733.68
	O 6+	7	739.32	Eu 1 +	1	5.67	733.65
	O 6+	7	739.32	Gd 1 +	1	6.14	733.17
	O 6+	7	739.32	Tb 1 +	1	5.85	733.47
	O 6+	7	739.32	Dy 1 +	1	5.93	733.39
25	O 6+	7	739.32	Ho 1 +	1	6.02	733.29
	O 6+	7	739.32	Er 1 +	1	6.10	733.22
	O 6+	7	739.32	Tm 1 +	1	6.18	733.13
	O 6+	7	739.32	Yb 1 +	1	6.25	733.06
	O 6+	7	739.32	Lu 1 +	1	5.43	733.89
30	O 6+	7	739.32	Hf 1 +	1	6.60	732.72
	O 6+	7	739.32	Ta 1 +	1	7.89	731.42
	O 6+	7	739.32	W 1 +	1	7.98	731.34
	O 6+	7	739.32	Re 1 +	1	7.88	731.43
	O 6+	7	739.32	Os 1 +	1	8.70	730.61
35	O 6+	7	739.32	Ir 1 +	1	9.10	730.22
	O 6+	7	739.32	Pt 1 +	1	9.00	730.32

O 6+	7	739.32	Au 1 +	1	9.23	730.09
O 6+	7	739.32	Tl 1 +	1	6.11	733.21
O 6+	7	739.32	Pb 1 +	1	7.42	731.90
O 6+	7	739.32	Bi 1 +	1	7.29	732.03
O 6+	7	739.32	Po 1 +	1	8.42	730.90
O 6+	7	739.32	Ra 1 +	1	5.28	734.04
O 6+	7	739.32	Ac 1 +	1	5.20	734.11
O 6+	7	739.32	Th 1 +	1	6.10	733.22
O 6+	7	739.32	Pa 1 +	1	5.90	733.41
O 6+	7	739.32	U 1 +	1	6.05	733.27
O 6+	7	739.32	Np 1 +	1	6.20	733.11
O 6+	7	739.32	Pu 1 +	1	6.06	733.26
O 6+	7	739.32	Am 1 +	1	5.99	733.33
O 6+	7	739.32	Cm 1 +	1	6.02	733.29
O 6+	7	739.32	Bk 1 +	1	6.23	733.09
O 6+	7	739.32	Cf 1 +	1	6.30	733.02
O 6+	7	739.32	Es 1 +	1	6.42	732.90
O 7+	8	871.39	O 6+	6	138.12	733.27
O 7+	8	871.39	Na 5 +	5	138.39	733.00
O 7+	8	871.39	Mg 5 +	5	141.26	730.13
O 7+	8	871.39	Sc 7 +	7	138.00	733.39
O 7+	8	871.39	Ti 7 +	7	140.80	730.59
O 7+	8	871.39	Cu 7 +	7	139.00	732.39
O 7+	8	871.39	Zn 7 +	7	134.00	737.39
O 7+	8	871.39	Rb 8 +	8	136.00	735.39
O 7+	8	871.39	Te 7 +	7	137.00	734.39
F 7+	8	953.89	P 6 +	6	220.43	733.46

Two-ion couples capable of producing energy holes for shrinking deuterium atoms involving cations and anions. The number in the column following the ion, (n), is the nth ionization energy of the atom. For example, Ga^{2+} + 30.71 eV = Ga^{3+} + e^- and H + e^- = H^- + 3.08 eV.

Atom Oxidized	n	nth Ionization Energy (eV)	Atom Reduced	n	nth Ionization Energy (eV)	Energy Hole (eV)

	As 2 +	3	28.35	H	- 1	0.80	27.55
	Ru 2 +	3	28.47	H	- 1	0.80	27.67
	In 2 +	3	28.03	H	- 1	0.80	27.23
	Te 2 +	3	27.96	H	- 1	0.80	27.16
5	Al 2 +	3	28.45	H	- 1	0.80	27.65
	Ar 1 +	2	27.63	H	- 1	0.80	26.83
	As 2 +	3	28.35	Li	- 1	0.61	27.74
	Ru 2 +	3	28.47	Li	- 1	0.61	27.86
	In 2 +	3	28.03	Li	- 1	0.61	27.42
10	Te 2 +	3	27.96	Li	- 1	0.61	27.35
	Al 2 +	3	28.45	Li	- 1	0.61	27.84
	Ar 1 +	2	27.63	Li	- 1	0.61	27.02
	Ti 2 +	3	27.49	Li	- 1	0.61	26.88
	As 2 +	3	28.35	B	- 1	0.30	28.05
15	Rb 1 +	2	27.28	B	- 1	0.30	26.98
	Mo 2 +	3	27.16	B	- 1	0.30	26.86
	Ru 2 +	3	28.47	B	- 1	0.30	28.17
	In 2 +	3	28.03	B	- 1	0.30	27.73
	Te 2 +	3	27.96	B	- 1	0.30	27.66
20	Al 2 +	3	28.45	B	- 1	0.30	28.15
	Ar 1 +	2	27.63	B	- 1	0.30	27.33
	Ti 2 +	3	27.49	B	- 1	0.30	27.19
	As 2 +	3	28.35	C	- 1	1.12	27.23
	Tc 2 +	3	29.54	C	- 1	1.12	28.42
25	Ru 2 +	3	28.47	C	- 1	1.12	27.35
	In 2 +	3	28.03	C	- 1	1.12	26.91
	Te 2 +	3	27.96	C	- 1	1.12	26.84
	N 1 +	2	29.60	C	- 1	1.12	28.48
	Al 2 +	3	28.45	C	- 1	1.12	27.33
30	V 2 +	3	29.31	C	- 1	1.12	28.19
	As 2 +	3	28.35	O	- 1	1.47	26.89
	Tc 2 +	3	29.54	O	- 1	1.47	28.07
	Ru 2 +	3	28.47	O	- 1	1.47	27.00
	Tl 2 +	3	29.83	O	- 1	1.47	28.36
35	N 1 +	2	29.60	O	- 1	1.47	28.14
	Al 2 +	3	28.45	O	- 1	1.47	26.98

	V 2 +	3	29.31	O	- 1	1.47	27.84
	Ga 2 +	3	30.71	F	- 1	3.45	27.26
	Se 2 +	3	30.82	F	- 1	3.45	27.37
	Rh 2 +	3	31.06	F	- 1	3.45	27.61
5	Sn 2 +	3	30.50	F	- 1	3.45	27.05
	Pb 2 +	3	31.94	F	- 1	3.45	28.49
	K 1 +	2	31.63	F	- 1	3.45	28.18
	Cr 2 +	3	30.96	F	- 1	3.45	27.51
	Fe 2	3	30.65	F	- 1	3.45	27.20
10	As 2 +	3	28.35	Na	- 1	0.52	27.83
	Ru 2 +	3	28.47	Na	- 1	0.52	27.95
	In 2 +	3	28.03	Na	- 1	0.52	27.51
	Te 2 +	3	27.96	Na	- 1	0.52	27.44
	Al 2 +	3	28.45	Na	- 1	0.52	27.93
15	Ar 1 +	2	27.63	Na	- 1	0.52	27.11
	Ti 2 +	3	27.49	Na	- 1	0.52	26.97
	As 2 +	3	28.35	Al	- 1	0.52	27.83
	Ru 2 +	3	28.47	Al	- 1	0.52	27.95
	In 2 +	3	28.03	Al	- 1	0.52	27.51
20	Te 2 +	3	27.96	Al	- 1	0.52	27.44
	Al 2 +	3	28.45	Al	- 1	0.52	27.93
	Ar 1 +	2	27.63	Al	- 1	0.52	27.11
	Ti 2 +	3	27.49	Al	- 1	0.52	26.97
	As 2 +	3	28.35	Si	- 1	1.39	26.96
25	Tc 2 +	3	29.54	Si	- 1	1.39	28.15
	Ru 2 +	3	28.47	Si	- 1	1.39	27.08
	Tl 2 +	3	29.83	Si	- 1	1.39	28.44
	N 1 +	2	29.60	Si	- 1	1.39	28.21
	Al 2 +	3	28.45	Si	- 1	1.39	27.06
30	V 2 +	3	29.31	Si	- 1	1.39	27.92
	As 2 +	3	28.35	P	- 1	0.78	27.57
	Ru 2 +	3	28.47	P	- 1	0.78	27.69
	In 2 +	3	28.03	P	- 1	0.78	27.25
	Te 2 +	3	27.96	P	- 1	0.78	27.18
35	Al 2 +	3	28.45	P	- 1	0.78	27.67
	Ar 1 +	2	27.63	P	- 1	0.78	26.85

	Tc 2 +	3	29.54	S	- 1	2.07	27.47
	Sn 2 +	3	30.50	S	- 1	2.07	28.43
	Tl 2 +	3	29.83	S	- 1	2.07	27.76
	N 1 +	2	29.60	S	- 1	2.07	27.53
5	P 2 +	3	30.18	S	- 1	2.07	28.11
	V 2 +	3	29.31	S	- 1	2.07	27.24
	Ga 2 +	3	30.71	Cl	- 1	3.61	27.10
	Se 2 +	3	30.82	Cl	- 1	3.61	27.21
	Rh 2 +	3	31.06	Cl	- 1	3.61	27.45
10	Sn 2 +	3	30.50	Cl	- 1	3.61	26.89
	Xe 2 +	3	32.10	Cl	- 1	3.61	28.49
	Pb 2 +	3	31.94	Cl	- 1	3.61	28.32
	K 1 +	2	31.63	Cl	- 1	3.61	28.01
	Cr 2 +	3	30.96	Cl	- 1	3.61	27.35
15	Fe 2 +	3	30.65	Cl	- 1	3.61	27.04
	As 2 +	3	28.35	K	- 1	0.69	27.66
	Ru 2 +	3	28.47	K	- 1	0.69	27.78
	In 2 +	3	28.03	K	- 1	0.69	27.34
	Te 2 +	3	27.96	K	- 1	0.69	27.27
20	Al 2 +	3	28.45	K	- 1	0.69	27.75
	Ar 1 +	2	27.63	K	- 1	0.69	26.93
	As 2 +	3	28.35	Fe	- 1	0.56	27.79
	Ru 2 +	3	28.47	Fe	- 1	0.56	27.91
	In 2 +	3	28.03	Fe	- 1	0.56	27.47
25	Te 2 +	3	27.96	Fe	- 1	0.56	27.40
	Al 2 +	3	28.45	Fe	- 1	0.56	27.89
	Ar 1 +	2	27.63	Fe	- 1	0.56	27.07
	Ti 2 +	3	27.49	Fe	- 1	0.56	26.93
	As 2 +	3	28.35	Co	- 1	0.95	27.40
30	Ru 2 +	3	28.47	Co	- 1	0.95	27.52
	In 2 +	3	28.03	Co	- 1	0.95	27.08
	Te 2 +	3	27.96	Co	- 1	0.95	27.01
	Al 2 +	3	28.45	Co	- 1	0.95	27.49
	V 2 +	3	29.31	Co	- 1	0.95	28.36
35	Tc 2 +	3	29.54	Cu	- 1	1.82	27.72
	Tl 2 +	3	29.83	Cu	- 1	1.82	28.01

	N 1 +	2	29.60	Cu	- 1	1.82	27.78
	P 2 +	3	30.18	Cu	- 1	1.82	28.36
	V 2 +	3	29.31	Cu	- 1	1.82	27.49
	Ga 2 +	3	30.71	Br	- 1	3.36	27.35
5	Se 2 +	3	30.82	Br	- 1	3.36	27.46
	Rh 2 +	3	31.06	Br	- 1	3.36	27.70
	Sn 2 +	3	30.50	Br	- 1	3.36	27.14
	P 2 +	3	30.18	Br	- 1	3.36	26.82
	K 1 +	2	31.63	Br	- 1	3.36	28.26
10	Cr 2 +	3	30.96	Br	- 1	3.36	27.60
	Fe 2 +	3	30.65	Br	- 1	3.36	27.29
	As 2 +	3	28.35	Rb	- 1	0.30	28.05
	Rb 1 +	2	27.28	Rb	- 1	0.30	26.98
	Mo 2 +	3	27.16	Rb	- 1	0.30	26.86
15	Ru 2 +	3	28.47	Rb	- 1	0.30	28.17
	In 2 +	3	28.03	Rb	- 1	0.30	27.73
	Te 2 +	3	27.96	Rb	- 1	0.30	27.66
	Al 2 +	3	28.45	Rb	- 1	0.30	28.15
	Ar 1 +	2	27.63	Rb	- 1	0.30	27.33
20	Ti 2 +	3	27.49	Rb	- 1	0.30	27.19
	Ga 2 +	3	30.71	I	- 1	3.06	27.65
	Se 2 +	3	30.82	I	- 1	3.06	27.76
	Rh 2 +	3	31.06	I	- 1	3.06	28.00
	Sn 2 +	3	30.50	I	- 1	3.06	27.44
25	P 2 +	3	30.18	I	- 1	3.06	27.12
	Cr 2 +	3	30.96	I	- 1	3.06	27.90
	Fe 2 +	3	30.65	I	- 1	3.06	27.59
	As 2 +	3	28.35	Cs	- 1	0.30	28.05
	Rb 1 +	2	27.28	Cs	- 1	0.30	26.98
30	Mo 2 +	3	27.16	Cs	- 1	0.30	26.86
	Ru 2 +	3	28.47	Cs	- 1	0.30	28.17
	In 2 +	3	28.03	Cs	- 1	0.30	27.73
	Te 2 +	3	27.96	Cs	- 1	0.30	27.66
	Al 2 +	3	28.45	Cs	- 1	0.30	28.15
35	Ar 1 +	2	27.63	Cs	- 1	0.30	27.33
	Ti 2 +	3	27.49	Cs	- 1	0.30	27.19

	Tc 2 +	3	29.54	Se	- 1	1.70	27.84
	Tl 2 +	3	29.83	Se	- 1	1.70	28.13
	N 1 +	2	29.60	Se	- 1	1.70	27.90
	P 2 +	3	30.18	Se	- 1	1.70	28.48
5	V 2 +	3	29.31	Se	- 1	1.70	27.61
	Tc 2 +	3	29.54	Te	- 1	2.20	27.34
	Sn 2 +	3	30.50	Te	- 1	2.20	28.30
	Tl 2 +	3	29.83	Te	- 1	2.20	27.63
	N 1 +	2	29.60	Te	- 1	2.20	27.40
10	P 2 +	3	30.18	Te	- 1	2.20	27.98
	V 2 +	3	29.31	Te	- 1	2.20	27.11
	Fe 2 +	3	30.65	Te	- 1	2.20	28.45
	As 2 +	3	28.35	As	- 1	0.60	27.75
	Ru 2 +	3	28.47	As	- 1	0.60	27.87
15	In 2 +	3	28.03	As	- 1	0.60	27.43
	Te 2 +	3	27.96	As	- 1	0.60	27.36
	Al 2 +	3	28.45	As	- 1	0.60	27.85
	Ar 1 +	2	27.63	As	- 1	0.60	27.03
	Ti 2 +	3	27.49	As	- 1	0.60	26.89
20	Tc 2 +	3	29.54	Sb	- 1	2.00	27.54
	Tl 2 +	3	29.83	Sb	- 1	2.00	27.83
	N 1 +	2	29.60	Sb	- 1	2.00	27.60
	P 2 +	3	30.18	Sb	- 1	2.00	28.18
	V 2 +	3	29.31	Sb	- 1	2.00	27.31
25	As 2 +	3	28.35	Bi	- 1	0.70	27.65
	Ru 2 +	3	28.47	Bi	- 1	0.70	27.77
	In 2 +	3	28.03	Bi	- 1	0.70	27.33
	Te 2 +	3	27.96	Bi	- 1	0.70	27.26
	Al 2 +	3	28.45	Bi	- 1	0.70	27.75
30	Ar 1 +	2	27.63	Bi	- 1	0.70	26.93
	Tc 2 +	3	29.54	Tl	- 1	2.10	27.44
	Sn 2 +	3	30.50	Tl	- 1	2.10	28.40
	Tl 2 +	3	29.83	Tl	- 1	2.10	27.73
	N 1 +	2	29.60	Tl	- 1	2.10	27.50
35	P 2 +	3	30.18	Tl	- 1	2.10	28.08
	V 2 +	3	29.31	Tl	- 1	2.10	27.21

Tc 2 +	3	29.54	Au	- 1	2.10	27.44
Sn 2 +	3	30.50	Au	- 1	2.10	28.40
Tl 2 +	3	29.83	Au	- 1	2.10	27.73
N 1 +	2	29.60	Au	- 1	2.10	27.50
P 2 +	3	30.18	Au	- 1	2.10	28.08
V 2 +	3	29.31	Au	- 1	2.10	27.21
As 2 +	3	28.35	Hg	- 1	1.54	26.81
Tc 2 +	3	29.54	Hg	- 1	1.54	28.00
Ru 2 +	3	28.47	Hg	- 1	1.54	26.93
Tl 2 +	3	29.83	Hg	- 1	1.54	28.29
N 1 +	2	29.60	Hg	- 1	1.54	28.06
Al 2 +	3	28.45	Hg	- 1	1.54	26.91
V 2 +	3	29.31	Hg	- 1	1.54	27.77
As 2 +	3	28.35	As	- 1	0.60	27.75
Ru 2 +	3	28.47	As	- 1	0.60	27.87
In 2 +	3	28.03	As	- 1	0.60	27.43
Te 2 +	3	27.96	As	- 1	0.60	27.36
Al 2 +	3	28.45	As	- 1	0.60	27.85
Ar 1 +	2	27.63	As	- 1	0.60	27.03
Ti 2 +	3	27.49	As	- 1	0.60	26.89
As 2 +	3	28.35	Ce	- 1	1.20	27.15
Tc 2 +	3	29.54	Ce	- 1	1.20	28.34
Ru 2 +	3	28.47	Ce	- 1	1.20	27.27
In 2 +	3	28.03	Ce	- 1	1.20	26.83
N 1 +	2	29.60	Ce	- 1	1.20	28.40
Al 2 +	3	28.45	Ce	- 1	1.20	27.25
V 2 +	3	29.31	Ce	- 1	1.20	28.11
As 2 +	3	28.35	Fr	- 1	0.46	27.89
Rb 1 +	2	27.28	Fr	- 1	0.46	26.82
Ru 2 +	3	28.47	Fr	- 1	0.46	28.01
In 2 +	3	28.03	Fr	- 1	0.46	27.57
Te 2 +	3	27.96	Fr	- 1	0.46	27.50
Al 2 +	3	28.45	Fr	- 1	0.46	27.99
Ar 1 +	2	27.63	Fr	- 1	0.46	27.17
Ti 2 +	3	27.49	Fr	- 1	0.46	27.03
As 2 +	3	28.35	Ge	- 1	1.20	27.15

	Tc 2 +	3	29.54	Ge	- 1	1.20	28.34
	Ru 2 +	3	28.47	Ge	- 1	1.20	27.27
	In 2 +	3	28.03	Ge	- 1	1.20	26.83
	N 1 +	2	29.60	Ge	- 1	1.20	28.40
5	Al 2 +	3	28.45	Ge	- 1	1.20	27.25
	V 2 +	3	29.31	Ge	- 1	1.20	28.11
	As 2 +	3	28.35	Sn	- 1	1.25	27.10
	Tc 2 +	3	29.54	Sn	- 1	1.25	28.29
	Ru 2 +	3	28.47	Sn	- 1	1.25	27.22
10	N 1 +	2	29.60	Sn	- 1	1.25	28.35
	Al 2 +	3	28.45	Sn	- 1	1.25	27.20
	V 2 +	3	29.31	Sn	- 1	1.25	28.06
	As 2 +	3	28.35	Pb	- 1	1.05	27.30
	Tc 2 +	3	29.54	Pb	- 1	1.05	28.49
15	Ru 2 +	3	28.47	Pb	- 1	1.05	27.42
	In 2 +	3	28.03	Pb	- 1	1.05	26.98
	Te 2 +	3	27.96	Pb	- 1	1.05	26.91
	Al 2 +	3	28.45	Pb	- 1	1.05	27.40
	V 2 +	3	29.31	Pb	- 1	1.05	28.26
20	Tc 2 +	3	29.54	Po	- 1	1.80	27.74
	Tl 2 +	3	29.83	Po	- 1	1.80	28.03
	N 1 +	2	29.60	Po	- 1	1.80	27.80
	P 2 +	3	30.18	Po	- 1	1.80	28.38
	V 2 +	3	29.31	Po	- 1	1.80	27.51
25	Ga 2 +	3	30.71	At	- 1	2.80	27.91
	Se 2 +	3	30.82	At	- 1	2.80	28.02
	Rh 2 +	3	31.06	At	- 1	2.80	28.26
	Sn 2 +	3	30.50	At	- 1	2.80	27.70
	Tl 2 +	3	29.83	At	- 1	2.80	27.03
30	N 1 +	2	29.60	At	- 1	2.80	26.80
	P 2 +	3	30.18	At	- 1	2.80	27.38
	Cr 2 +	3	30.96	At	- 1	2.80	28.16
	Fe 2 +	3	30.65	At	- 1	2.80	27.85
	As 2 +	3	28.35	Ge	- 1	1.20	27.15
35	Tc 2 +	3	29.54	Ge	- 1	1.20	28.34
	Ru 2 +	3	28.47	Ge	- 1	1.20	27.27

In 2 +	3	28.03	Ge	- 1	1.20	26.83
N 1 +	2	29.60	Ge	- 1	1.20	28.40
Al 2 +	3	28.45	Ge	- 1	1.20	27.25
V 2 +	3	29.31	Ge	- 1	1.20	28.11
As 2 +	3	28.35	Ga	- 1	0.37	27.98
Rb 1 +	2	27.28	Ga	- 1	0.37	26.91
Ru 2 +	3	28.47	Ga	- 1	0.37	28.10
In 2 +	3	28.03	Ga	- 1	0.37	27.66
Te 2 +	3	27.96	Ga	- 1	0.37	27.59
Al 2 +	3	28.45	Ga	- 1	0.37	28.08
Ar 1 +	2	27.63	Ga	- 1	0.37	27.26
Ti 2 +	3	27.49	Ga	- 1	0.37	27.12
As 2 +	3	28.35	In	- 1	0.35	28.00
Rb 1 +	2	27.28	In	- 1	0.35	26.93
Mo 2 +	3	27.16	In	- 1	0.35	26.81
Ru 2 +	3	28.47	In	- 1	0.35	28.12
In 2 +	3	28.03	In	- 1	0.35	27.68
Te 2 +	3	27.96	In	- 1	0.35	27.61
Al 2 +	3	28.45	In	- 1	0.35	28.10
Ar 1 +	2	27.63	In	- 1	0.35	27.28
Ti 2 +	3	27.49	In	- 1	0.35	27.14
As 2 +	3	28.35	Ag	- 1	1.30	27.05
Tc 2 +	3	29.54	Ag	- 1	1.30	28.24
Ru 2 +	3	28.47	Ag	- 1	1.30	27.17
N 1 +	2	29.60	Ag	- 1	1.30	28.30
Al 2 +	3	28.45	Ag	- 1	1.30	27.15
V 2 +	3	29.31	Ag	- 1	1.30	28.01

Cations and anions with n = 16 (resonance shrinkage energy is given by $\frac{n}{2}$ 27.21; with n = 16, the resonance shrinkage energy is 217.68)

Atom Oxidized	n	nth Ionization Energy (eV)	Atom Reduced	n	nth Ionization Energy (eV)	Energy Hole (eV)
Be 3 +	4	217.71	H	- 1	0.80	216.91
Be 3 +	4	217.71	Li	- 1	0.61	217.10

Be 3 +	4	217.71	B	- 1	0.30	217.41
Be 3 +	4	217.71	C	- 1	1.12	216.59
Be 3 +	4	217.71	O	- 1	1.47	216.25
P 5 +	6	220.43	O	- 1	1.47	218.96
P 5 +	6	220.43	F	- 1	3.45	216.98
Be 3 +	4	217.71	Na	- 1	0.52	217.19
Be 3 +	4	217.71	Al	- 1	0.52	217.19
Be 3 +	4	217.71	Si	- 1	1.39	216.32
Be 3 +	4	217.71	P	- 1	0.78	216.94
Be 3 +	4	217.71	S	- 1	2.07	215.64
P 5 +	6	220.43	S	- 1	2.07	218.36
P 5 +	6	220.43	Cl	- 1	3.61	216.82
Be 3 +	4	217.71	K	- 1	0.69	217.02
Be 3 +	4	217.71	Fe	- 1	0.56	217.15
Be 3 +	4	217.71	Co	- 1	0.95	216.76
Be 3 +	4	217.71	Cu	- 1	1.82	215.89
P 5 +	6	220.43	Cu	- 1	1.82	218.61
P 5 +	6	220.43	Br	- 1	3.36	217.07
Be 3 +	4	217.71	Rb	- 1	0.30	217.41
P 5 +	6	220.43	I	- 1	3.06	217.37
Be 3 +	4	217.71	Cs	- 1	0.30	217.41
Be 3 +	4	217.71	Se	- 1	1.70	216.01
P 5 +	6	220.43	Se	- 1	1.70	218.73
P 5 +	6	220.43	Te	- 1	2.20	218.23
Be 3 +	4	217.71	As	- 1	0.60	217.11
P 5 +	6	220.43	As	- 1	0.60	219.83
P 5 +	6	220.43	Sb	- 1	2.00	218.43
Be 3 +	4	217.71	Bi	- 1	0.70	217.01
P 5 +	6	220.43	Bi	- 1	0.70	219.73
P 5 +	6	220.43	Tl	- 1	2.10	218.33
P 5 +	6	220.43	Au	- 1	2.10	218.33
Be 3 +	4	217.71	Hg	- 1	1.54	216.17
P 5 +	6	220.43	Hg	- 1	1.54	218.89
Be 3 +	4	217.71	As	- 1	0.60	217.11
P 5 +	6	220.43	As	- 1	0.60	219.83
Be 3 +	4	217.71	Ce	- 1	1.20	216.51

	P 5+	6	220.43	Ce	- 1	1.20	219.23
	Be 3+	4	217.71	Fr	- 1	0.46	217.25
	P 5+	6	220.43	Fr	- 1	0.46	219.97
	Be 3+	4	217.71	Ge	- 1	1.20	216.51
5	P 5+	6	220.43	Ge	- 1	1.20	219.23
	Be 3+	4	217.71	Sn	- 1	1.25	216.46
	P 5+	6	220.43	Sn	- 1	1.25	219.18
	Be 3+	4	217.71	Pb	- 1	1.05	216.66
	P 5+	6	220.43	Pb	- 1	1.05	219.38
10	P 5+	6	220.43	Po	- 1	1.80	218.63
	P 5+	6	220.43	At	- 1	2.80	217.63
	Be 3+	4	217.71	Ge	- 1	1.20	216.51
	P 5+	6	220.43	Ge	- 1	1.20	219.23
	Be 3+	4	217.71	Ga	- 1	0.37	217.34
15	Be 3+	4	217.71	In	- 1	0.35	217.36
	Be 3+	4	217.71	Ag	- 1	1.30	216.41
	P 5+	6	220.43	Ag	- 1	1.30	219.13

Cations and anions with n = 54 (resonance shrinkage energy is given by $\frac{n}{2}$ 27.21; with n = 54, the resonance shrinkage energy is

20 734.67)

Atom Oxidized	n	nth Ionization Energy (eV)	Atom Reduced	n	nth Ionization Energy (eV)	Energy Hole (eV)
25 O 6+	7	739.32	H	- 1	0.80	738.52
O 6+	7	739.32	Li	- 1	0.61	738.70
O 6+	7	739.32	C	- 1	1.12	738.20
O 6+	7	739.32	O	- 1	1.47	737.85
O 6+	7	739.32	F	- 1	3.45	735.87
30 O 6+	7	739.32	Na	- 1	0.52	738.80
O 6+	7	739.32	Al	- 1	0.52	738.80
O 6+	7	739.32	Si	- 1	1.39	737.93
O 6+	7	739.32	P	- 1	0.78	738.54
O 6+	7	739.32	S	- 1	2.07	737.24
35 O 6+	7	739.32	Cl	- 1	3.61	735.70

O 6+	7	739.32	K	- 1	0.69	738.62
O 6+	7	739.32	Fe	- 1	0.56	738.76
O 6+	7	739.32	Co	- 1	0.95	738.36
O 6+	7	739.32	Cu	- 1	1.82	737.49
O 6+	7	739.32	Br	- 1	3.36	735.95
O 6+	7	739.32	I	- 1	3.06	736.25
O 6+	7	739.32	Se	- 1	1.70	737.61
O 6+	7	739.32	Te	- 1	2.20	737.11
O 6+	7	739.32	As	- 1	0.60	738.72
O 6+	7	739.32	Sb	- 1	2.00	737.32
O 6+	7	739.32	Bi	- 1	0.70	738.61
O 6+	7	739.32	Tl	- 1	2.10	737.22
O 6+	7	739.32	Au	- 1	2.10	737.22
O 6+	7	739.32	Hg	- 1	1.54	737.78
O 6+	7	739.32	As	- 1	0.60	738.72
O 6+	7	739.32	Ce	- 1	1.20	738.11
O 6+	7	739.32	Fr	- 1	0.46	738.85
O 6+	7	739.32	Ge	- 1	1.20	738.11
O 6+	7	739.32	Sn	- 1	1.25	738.07
O 6+	7	739.32	Pb	- 1	1.05	738.27
O 6+	7	739.32	Po	- 1	1.80	737.52
O 6+	7	739.32	At	- 1	2.80	736.52
O 6+	7	739.32	Ge	- 1	1.20	738.11
O 6+	7	739.32	Ga	- 1	0.37	738.95
O 6+	7	739.32	In	- 1	0.35	738.97
O 6+	7	739.32	Ag	- 1	1.30	738.02

Some representative couples comprising a cation and a molecule capable of producing energy holes for shrinking deuterium atoms where the molecule is reduced. The number in the column following the ion or molecule, (n), is the nth ionization energy of the atom or molecule. For example, Ga^{2+} + 30.71 eV = Ga^{3+} + e^- and BF_3 + e^- = BF_3 + 2.65 eV.

Atom Oxidized	n	nth Ionization Energy (eV)	Atom Reduced	n	nth Ionization Energy (eV)	Energy Hole (eV)

Ga 2 +	3	30.71	BF_3	- 1	2.65	28.06
Se 2 +	3	30.82	BF_3	- 1	2.65	28.17
Tc 2 +	3	29.54	BF_3	- 1	2.65	26.89
Rh 2 +	3	31.06	BF_3	- 1	2.65	28.41
Sn 2 +	3	30.50	BF_3	- 1	2.65	27.85
Tl 2 +	3	29.83	BF_3	- 1	2.65	27.18
N 1 +	2	29.60	BF_3	- 1	2.65	26.95
P 2 +	3	30.18	BF_3	- 1	2.65	27.53
Cr 2 +	3	30.96	BF_3	- 1	2.65	28.31
Fe 2 +	3	30.65	BF_3	- 1	2.65	28.00
Se 2 +	3	30.82	NO_2	- 1	3.91	26.91
Rh 2 +	3	31.06	NO_2	- 1	3.91	27.15
Xe 2 +	3	32.10	NO_2	- 1	3.91	28.19
Pb 2 +	3	31.94	NO_2	- 1	3.91	28.03
K 1 +	2	31.63	NO_2	- 1	3.91	27.72
Cr 2 +	3	30.96	NO_2	- 1	3.91	27.05
As 2 +	3	28.35	O_2	- 1	0.45	27.90
Rb 1 +	2	27.28	O_2	- 1	0.45	26.83
Ru 2 +	3	28.47	O_2	- 1	0.45	28.02
In 2 +	3	28.03	O_2	- 1	0.45	27.58
Te 2 +	3	27.96	O_2	- 1	0.45	27.51
Al 2 +	3	28.45	O_2	- 1	0.45	28.00
Ar 1 +	2	27.63	O_2	- 1	0.45	27.18
Ti 2 +	3	27.49	O_2	- 1	0.45	27.04
As 2 +	3	28.35	SF_6	- 1	1.43	26.92
Tc 2 +	3	29.54	SF_6	- 1	1.43	28.11
Ru 2 +	3	28.47	SF_6	- 1	1.43	27.04
Tl 2 +	3	29.83	SF_6	- 1	1.43	28.40
N 1 +	2	29.60	SF_6	- 1	1.43	28.17
Al 2 +	3	28.45	SF_6	- 1	1.43	27.02
V 2 +	3	29.31	SF_6	- 1	1.43	27.88
Ga 2 +	3	30.71	WF_6	- 1	2.74	27.97
Se 2 +	3	30.82	WF_6	- 1	2.74	28.08
Tc 2 +	3	29.54	WF_6	- 1	2.74	26.80
Rh 2 +	3	31.06	WF_6	- 1	2.74	28.32
Sn 2 +	3	30.50	WF_6	- 1	2.74	27.76

	Tl 2 +	3	29.83	WF_6	- 1	2.74	27.09
	N 1 +	2	29.60	WF_6	- 1	2.74	26.86
	P 2 +	3	30.18	WF_6	- 1	2.74	27.44
	Cr 2 +	3	30.96	WF_6	- 1	2.74	28.22
5	Fe 2 +	3	30.65	WF_6	- 1	2.74	27.91
	Ga 2 +	3	30.71	UF_6	- 1	2.91	27.80
	Se 2 +	3	30.82	UF_6	- 1	2.91	27.91
	Rh 2 +	3	31.06	UF_6	- 1	2.91	28.15
	Sn 2 +	3	30.50	UF_6	- 1	2.91	27.59
10	Tl 2 +	3	29.83	UF_6	- 1	2.91	26.92
	P 2 +	3	30.18	UF_6	- 1	2.91	27.27
	Cr 2 +	3	30.96	UF_6	- 1	2.91	28.05
	Fe 2 +	3	30.65	UF_6	- 1	2.91	27.74
	Tc 2 +	3	29.54	CF_3	- 1	1.85	27.69
15	Tl 2 +	3	29.83	CF_3	- 1	1.85	27.98
	N 1 +	2	29.60	CF_3	- 1	1.85	27.75
	P 2 +	3	30.18	CF_3	- 1	1.85	28.33
	V 2 +	3	29.31	CF_3	- 1	1.85	27.46
	As 2 +	3	28.35	CCl_3	- 1	1.22	27.13
20	Tc 2 +	3	29.54	CCl_3	- 1	1.22	28.32
	Ru 2 +	3	28.47	CCl_3	- 1	1.22	27.25
	In 2 +	3	28.03	CCl_3	- 1	1.22	26.81
	N 1 +	2	29.60	CCl_3	- 1	1.22	28.38
	Al 2 +	3	28.45	CCl_3	- 1	1.22	27.23
25	V 2 +	3	29.31	CCl_3	- 1	1.22	28.09
	Ga 2 +	3	30.71	SiF_3	- 1	3.35	27.36
	Se 2 +	3	30.82	SiF_3	- 1	3.35	27.47
	Rh 2 +	3	31.06	SiF_3	- 1	3.35	27.71
	Sn 2 +	3	30.50	SiF_3	- 1	3.35	27.15
30	P 2 +	3	30.18	SiF_3	- 1	3.35	26.83
	K 1 +	2	31.63	SiF_3	- 1	3.35	28.27
	Cr 2 +	3	30.96	SiF_3	- 1	3.35	27.61
	Fe 2 +	3	30.65	SiF_3	- 1	3.35	27.30
	As 2 +	3	28.35	NH_2	- 1	1.12	27.23
35	Tc 2 +	3	29.54	NH_2	- 1	1.12	28.42
	Ru 2 +	3	28.47	NH_2	- 1	1.12	27.35

	In 2 +	3	28.03	NH_2	- 1	1.12	26.91
	Te 2 +	3	27.96	NH_2	- 1	1.12	26.84
	N 1 +	2	29.60	NH_2	- 1	1.12	28.48
	Al 2 +	3	28.45	NH_2	- 1	1.12	27.33
5	V 2 +	3	29.31	NH_2	- 1	1.12	28.19
	Tc 2 +	3	29.54	PH_2	- 1	1.60	27.94
	Ru 2 +	3	28.47	PH_2	- 1	1.60	26.87
	Tl 2 +	3	29.83	PH_2	- 1	1.60	28.23
	N 1 +	2	29.60	PH_2	- 1	1.60	28.00
10	Al 2 +	3	28.45	PH_2	- 1	1.60	26.85
	V 2 +	3	29.31	PH_2	- 1	1.60	27.71
	Tc 2 +	3	29.54	OH	- 1	1.83	27.71
	Tl 2 +	3	29.83	OH	- 1	1.83	28.00
	N 1 +	2	29.60	OH	- 1	1.83	27.77
15	P 2 +	3	30.18	OH	- 1	1.83	28.35
	V 2 +	3	29.31	OH	- 1	1.83	27.48
	Tc 2 +	3	29.54	SH	- 1	2.19	27.35
	Sn 2 +	3	30.50	SH	- 1	2.19	28.31
	Tl 2 +	3	29.83	SH	- 1	2.19	27.64
20	N 1 +	2	29.60	SH	- 1	2.19	27.41
	P 2 +	3	30.18	SH	- 1	2.19	27.99
	V 2 +	3	29.31	SH	- 1	2.19	27.12
	Fe 2 +	3	30.65	SH	- 1	2.19	28.46
	Ga 2 +	3	30.71	CN	- 1	3.17	27.54
25	Se 2 +	3	30.82	CN	- 1	3.17	27.65
	Rh 2 +	3	31.06	CN	- 1	3.17	27.89
	Sn 2 +	3	30.50	CN	- 1	3.17	27.33
	P 2 +	3	30.18	CN	- 1	3.17	27.01
	K 1 +	2	31.63	CN	- 1	3.17	28.45
30	Cr 2 +	3	30.96	CN	- 1	3.17	27.79
	Fe 2 +	3	30.65	CN	- 1	3.17	27.48
	Tc 2 +	3	29.54	SCN	- 1	2.17	27.37
	Sn 2 +	3	30.50	SCN	- 1	2.17	28.33
	Tl 2 +	3	29.83	SCN	- 1	2.17	27.66
35	N 1 +	2	29.60	SCN	- 1	2.17	27.43
	P 2 +	3	30.18	SCN	- 1	2.17	28.01

	V 2 +	3	29.31	SCN	- 1	2.17	27.14
	Fe 2 +	3	30.65	SCN	- 1	2.17	28.48
	Ga 2 +	3	30.71	SeCN	- 1	2.64	28.07
	Se 2 +	3	30.82	SeCN	- 1	2.64	28.18
5	Tc 2 +	3	29.54	SeCN	- 1	2.64	26.90
	Rh 2 +	3	31.06	SeCN	- 1	2.64	28.42
	Sn 2 +	3	30.50	SeCN	- 1	2.64	27.86
	Tl 2 +	3	29.83	SeCN	- 1	2.64	27.19
	N 1 +	2	29.60	SeCN	- 1	2.64	26.96
10	P 2 +	3	30.18	SeCN	- 1	2.64	27.54
	Cr 2 +	3	30.96	SeCN	- 1	2.64	28.32
	Fe 2 +	3	30.65	SeCN	- 1	2.64	28.01

Cations and molecular anions with n = 16 (resonance shrinkage energy is given by $\frac{n}{2}$ 27.21 with n = 16, the resonance

15 shrinkage energy is 217.68)

Atom Oxidized	n	nth Ionization Energy (eV)	Atom Reduced	n	nth Ionization Energy (eV)	Energy Hole (eV)
20 P 5 +	6	220.43	BF_3	- 1	2.65	217.78
P 5 +	6	220.43	NO_2	- 1	3.91	216.52
Be 3 +	4	217.71	O_2	- 1	0.45	217.26
P 5 +	6	220.43	O_2	- 1	0.45	219.98
Be 3 +	4	217.71	SF_6	- 1	1.43	216.28
25 P 5 +	6	220.43	SF_6	- 1	1.43	219.00
P 5 +	6	220.43	WF_6	- 1	2.74	217.69
P 5 +	6	220.43	UF_6	- 1	2.91	217.52
P 5 +	6	220.43	CF_3	- 1	1.85	218.58
Be 3 +	4	217.71	CCl_3	- 1	1.22	216.49
30 P 5 +	6	220.43	CCl_3	- 1	1.22	219.21
P 5 +	6	220.43	SiF_3	- 1	3.35	217.08
Be 3 +	4	217.71	NH_2	- 1	1.12	216.59
P 5 +	6	220.43	NH_2	- 1	1.12	219.31
Be 3 +	4	217.71	PH_2	- 1	1.60	216.11
35 P 5 +	6	220.43	PH_2	- 1	1.60	218.83

P 5+	6	220.43	OH	- 1	1.83	218.60
P 5+	6	220.43	SH	- 1	2.19	218.24
P 5+	6	220.43	CN	- 1	3.17	217.26
P 5+	6	220.43	SCN	- 1	2.17	218.26
P 5+	6	220.43	SeCN	- 1	2.64	217.79

Cations and molecular anions with n = 54 (resonance shrinkage energy is given by $\frac{n}{2}$ 27.21 with n = 54, the resonance shrinkage energy is 734.67)

Atom Oxidized	n	nth Ionization Energy (eV)	Atom Reduced	n	nth Ionization Energy (eV)	Energy Hole (eV)
O 6+	7	739.32	BF_3	- 1	2.65	736.66
O 6+	7	739.32	NO_2	- 1	3.91	735.41
O 6+	7	739.32	O_2	- 1	0.45	738.86
O 6+	7	739.32	SF_6	- 1	1.43	737.89
O 6+	7	739.32	WF_6	- 1	2.74	736.58
O 6+	7	739.32	UF_6	- 1	2.91	736.41
O 6+	7	739.32	CF_3	- 1	1.85	737.47
O 6+	7	739.32	CCl_3	- 1	1.22	738.10
O 6+	7	739.32	SiF_3	- 1	3.35	735.97
O 6+	7	739.32	NH_2	- 1	1.12	738.20
O 6+	7	739.32	PH_2	- 1	1.60	737.72
O 6+	7	739.32	OH	- 1	1.83	737.48
O 6+	7	739.32	SH	- 1	2.19	737.13
O 6+	7	739.32	CN	- 1	3.17	736.15
O 6+	7	739.32	SCN	- 1	2.17	737.15
O 6+	7	739.32	SeCN	- 1	2.64	736.67

26. The apparatus of claim 19, wherein said energy hole is provided by one of the following three-ion couples:

Atom Oxidized	(eV)	Atom(s) Reduced	(eV)	Energy Hole (eV)
B 3	37.48	Li 1	5.392	27.40
		Na 1	5.139	
Cd 3	37.48	Na 1	5.139	27.20

27. The apparatus of claim 17, further including:

external energy apparatus;

means for providing a transfer of energy between said juxtaposed first and second elements of matter and said substance, and said external energy apparatus for controlling the rate of said fusion according to the relative equivalence of said energy hole and resonance shrinkage energy transferred to said first and second elements of matter.

28. The apparatus of claim 27, wherein said means for providing a transfer of energy comprises means for applying one of an electric, a magnetic field, transfer of heat and acoustic energy to said selected volume.

29. The apparatus of claim 17, further comprising:

means for receiving said release of energy from said volume; and

means for transferring the received released energy to external load apparatus for dissipation and production of work.

30. The apparatus of claim 29, wherein:

said means for receiving comprises heat exchanger means for providing a flow of heat in a selected medium; and

said means for transferring comprises turbine means for receiving said heat flow and providing one of electrical and mechanical power therefrom.

31. A method of determining the energy levels of the electron orbitals of an element of matter, comprising the steps of:

determining the centripetal force of each electron orbital;

determining the gradient of said electrostatic potential of said element of matter;

determining the radius of each electron orbital shell according to the centripetal force and the gradient of said electrostatic potential; and

determine the energy level according to the radius of said electron orbital.

32. The method of claim 31, further providing the step of providing relativistic corrections of the determined energy.

33. The method of claim 31, where the steps of determining the gradient comprises:

$$f_{ele} = -\nabla \frac{e2}{4\pi\epsilon_o r}$$

and the step of determining the energy level according to the radius comprises:

$$f_{centripetal} = \frac{mv2}{r}$$

34. The method of claim 31, further including the steps of:

determining the gradient of the angular momentum of each said electron;

determining the radius of each Mills electron orbital shell according to the centripetal force, gradient of said electrostatic potential and the gradient of said angular momentum;

determining the electrostatic energy of each electron orbital according to the radius of each Mills electron orbital shell;

determining the magnetic energy of each electron orbital according to the radius of each electron orbital shell; and

adding the electrostatic and magnetic energy to provide said electron orbital energy level.

35. The method of claim 34, further including the step of providing relativistic correction of the determined energy.

36. A method of determining the internuclear distance of a chemical bond, comprising the steps of:

determining the decrease in electron electrostatic energy as internuclear distance 2y decreases;

determining the increase in nuclear repulsive energy as internuclear distance 2y decreases; and

determining the distance 2y at which point the change in electrostatic energy and nuclear repulsive energy are substantially equal, to provide the internuclear distance of a chemical bond, wherein

the total energy stored in the resulting electric field is a minimum.

37. For use in the production of coulombic annihilation fusion, an energy hole of energy E, comprising

a first element of matter selected according to a corresponding ionization potential; and

at least one second element of matter selected according to a corresponding ionization potential, wherein

the combination of the ionization potentials provides a net positive ionization potential substantially equal to E.

38. An apparatus of claim 22, wherein the source of an energy hole is a single cation, neutral atom, or anion or a single molecule which is a cation, neutral molecule or anion, or is a combination of said species wherein the said energy hole is substantially equivalent to n/2 27.21 eV where n = 2, 3; 4,... .

39. A method of releasing energy, comprising the steps of:

selecting a first element of matter having a nucleus and at least one electron orbital;

selecting a second element of matter having a nucleus and at least one electron orbital;

determining the resonance shrinkage energy levels of the electron orbitals of said first and second elements of matter;

providing two energy holes substantially equal to each of the resonance shrinkage energy levels of said first and second elements of matter;

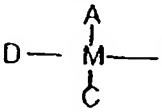
juxtaposing said first and second elements of matter and said energy holes, wherein;

a non-fusion release of energy is produced when the energy of said electron orbitals is removed by said energy holes.

40. A composition of matter, comprising:

a transition element, m, having a large population of electrons receptive of energy from one of an electric and magnetic field to urge formation of Cooper electron pairs; and

a plurality of materials, A, B, C, and D having strong bond energies and a lattice of two of less dimensions, wherein A, B, C, and D each are of different atoms, different oxidation states of the same atom, and different oxidation states of different atoms, in a cell arrangement,



having superconductor properties.

FIG. 1

CHARGE DENSITIES AS A FUNCTION OF SPACE

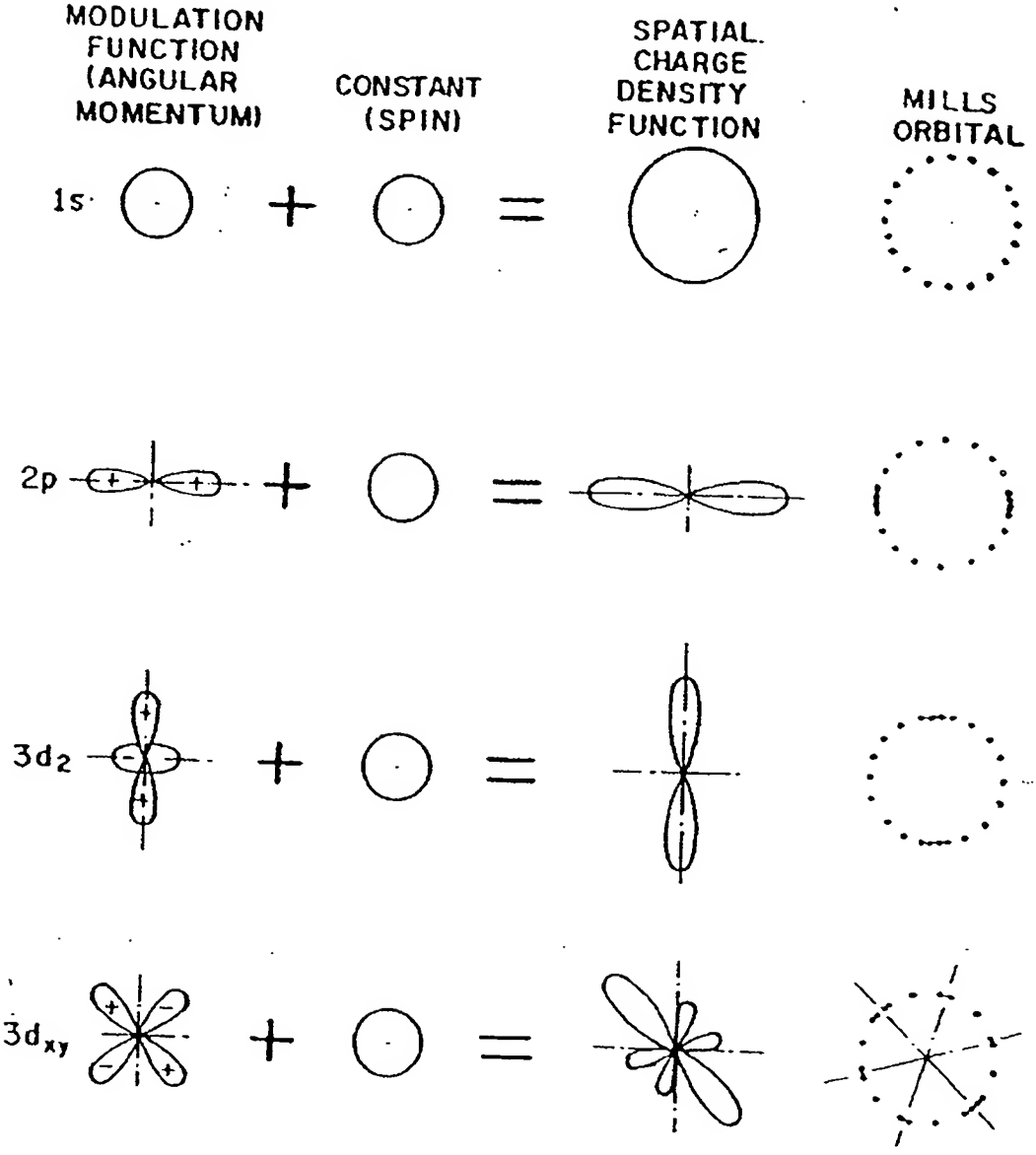


FIG. 2

THE MAGNETIC FIELD OF AN ELECTRON OF A MILLS ORBITAL IN AN UN-IONIZED STATE

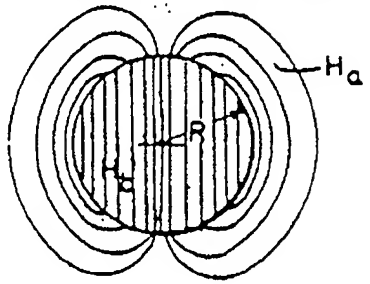
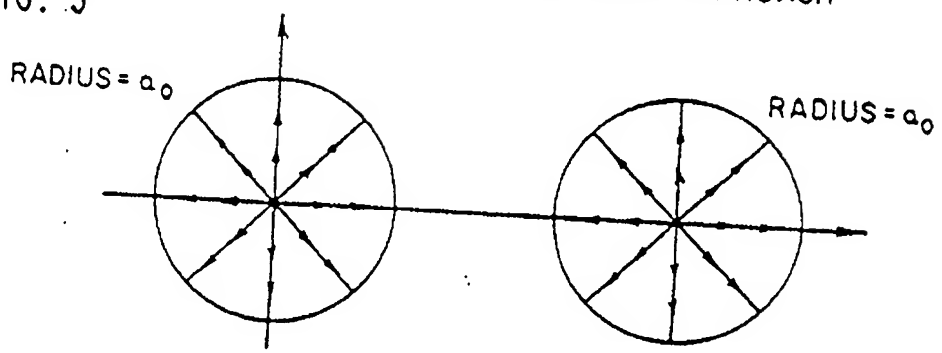
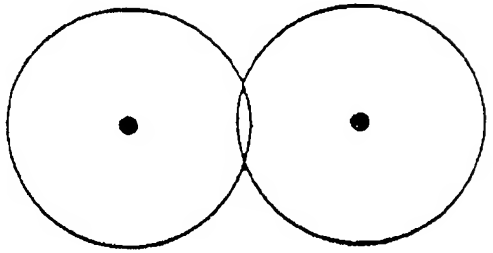


FIG. 3 TWO HYDROGEN ATOMS AS THEY APPROACH



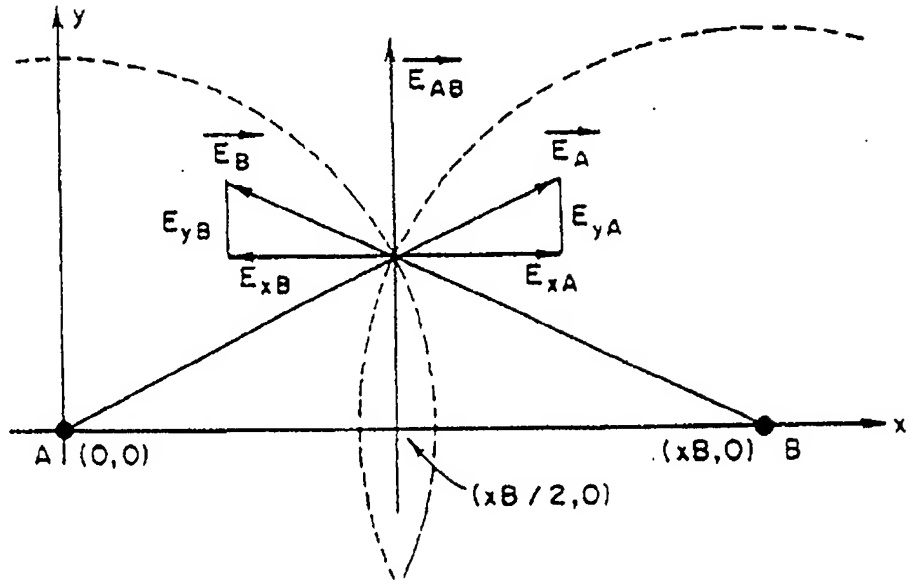
THE RADIAL ELECTRIC-FIELD VECTORS TEND TO CANCEL IN THE OVERLAP REIGON WHEN THE OVERLAP IS SMALL

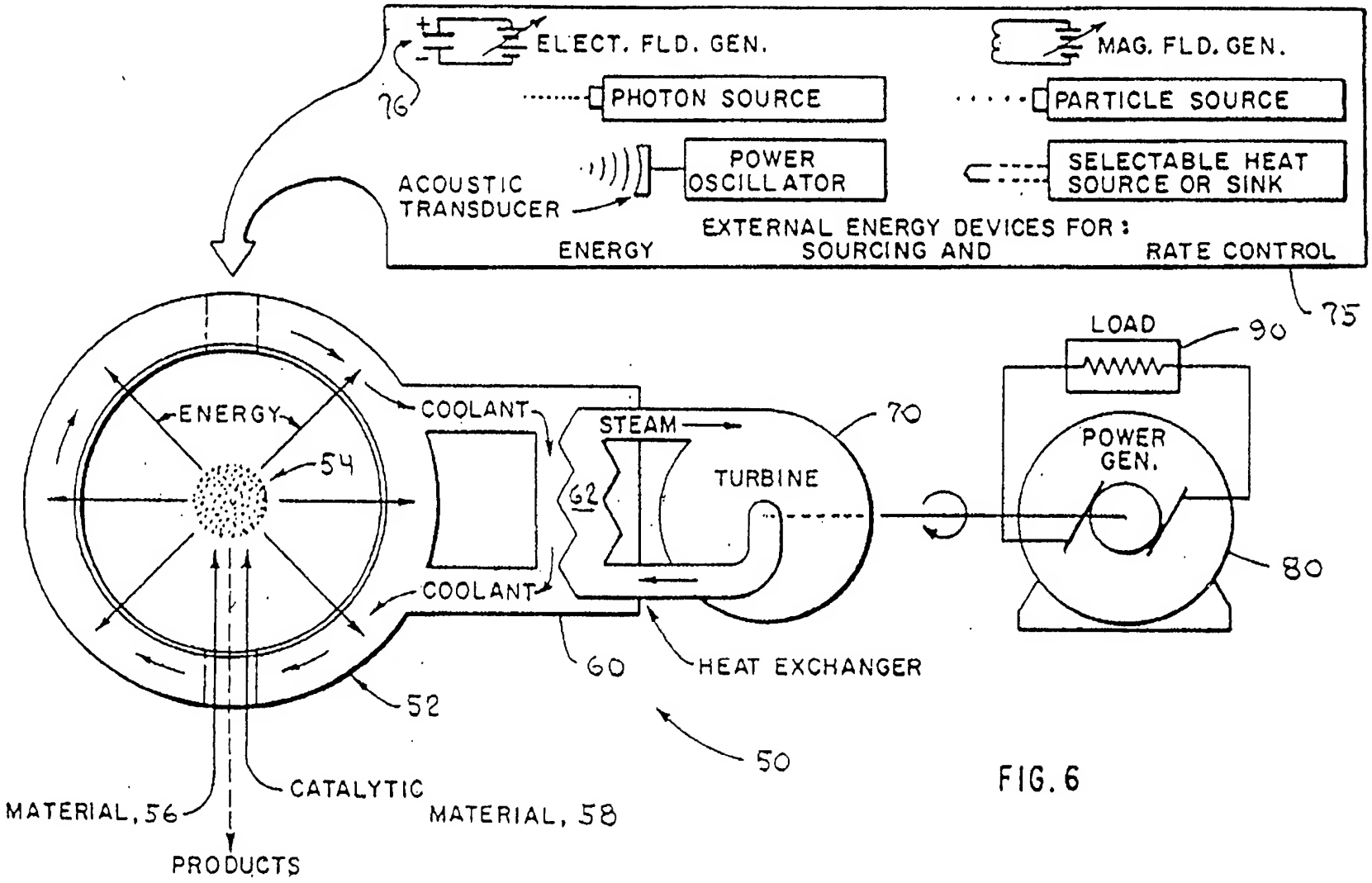
FIG. 4



A DIAGRAM OF THE ELECTRIC FIELD VECTORS WHEN THE MILLS ORBITALS OF TWO HYDROGEN ATOMS PENETRATE

FIG. 5




ELECT. FLD. GEN.
MAG. FLD. GEN.
76
PHOTON SOURCE
PARTICLE SOURCE
ACOUSTIC TRANSDUCER
POWER OSCILLATOR
SELECTABLE HEAT SOURCE OR SINK
EXTERNAL ENERGY DEVICES FOR: ENERGY SOURCING AND RATE CONTROL
75
LOAD
90
ENERGY
54
COOLANT
STEAM
70
62
TURBINE
POWER GEN.
80
COOLANT
60
HEAT EXCHANGER
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50
CATALYTIC MATERIAL, 58
MATERIAL, 56
PRODUCTS

FIG. 6

M20

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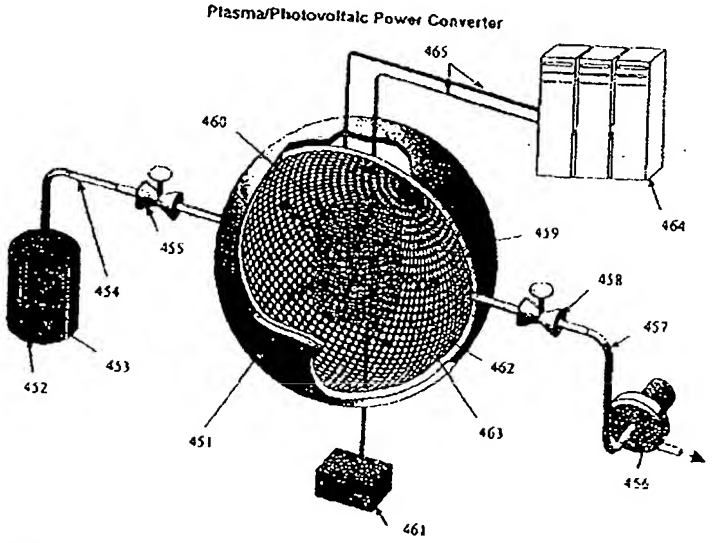
[Continued on next page]

(54) Title: HYDROGEN POWER, PLASMA, AND REACTOR FOR LASING, AND POWER CONVERSION



(57) Abstract: Provided is an inverted population of hydrogen, formed from a novel catalytic reaction of hydrogen atoms to form lower-energy hydrogen. The inverted population of hydrogen is capable of lasing. The power may be utilized as laser light or the light due to stimulated or spontaneous emission may be converted to electricity with a photon-to-electric converter such as a photovoltaic cell.

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Hydrogen Power, Plasma, and Reactor for Lasing, and Power Conversion

TABLE OF CONTENTS

Hydrogen Power, Plasma, and Reactor for Lasing, and Power Conversion

I. INTRODUCTION

1. Field of the Invention

This invention relates to a power source and a laser based on the power source wherein the power may also be converted to electricity with a power converter of the present invention. The power source comprises a cell for the catalysis of atomic hydrogen to form novel hydrogen species and/or compositions of matter comprising new forms of hydrogen. The reaction may be maintained by a microwave or glow discharge plasma of hydrogen and a source of catalyst. The power from the catalysis of hydrogen may create an inverted population of a species capable of lasing such as atomic hydrogen. The power may utilized as laser light or the light due to stimulated or spontaneous emission may be converted to electricity with a photon-to-electric converter such as a photovoltaic cell. In addition or alternatively, the thermal power may used for heating or be directly converted into electricity since it forms or contributes energy to the plasma. The plasma power may be converted to electricity by a magnetohydrodynamic power converter from a directional flow of ions formed using a magnetic mirror based on the adiabatic invariant $\frac{v_\perp^2}{B} = \text{constant}$. Alternatively, the power converter comprises plasmadynamic converter comprising a magnetic field which permits positive ions to be separated from electrons using at least one electrode to produce a voltage with respect to at least one counter electrode connected through a load. These and other methods and means to convert plasma into electricity are described in my prior published applications and articles , which are incorporated by reference in their entirety below.

2. Background of the Invention

2.1 Hydrinos

A hydrogen atom having a binding energy given by

$$Binding\ Energy = \frac{13.6\ eV}{\left(\frac{1}{p}\right)^2} \qquad (1)$$

where p is an integer greater than 1, preferably from 2 to 200, is disclosed in R. Mills, *The Grand Unified Theory of Classical Quantum Mechanics*, January 2000 Edition, BlackLight Power, Inc., Cranbury, New Jersey, Distributed by Amazon.com (" '00 Mills GUT"), provided by BlackLight Power, Inc., 493 Old Trenton Road, Cranbury, NJ, 08512; R. Mills, *The Grand*

Unified Theory of Classical Quantum Mechanics, September 2001 Edition, BlackLight Power, Inc., Cranbury, New Jersey, Distributed by Amazon.com (" '01 Mills GUT"), provided by BlackLight Power, Inc., 493 Old Trenton Road, Cranbury, NJ, 08512 (posted at www.blacklightpower.com; R. Mills, *The Grand Unified Theory of Classical Quantum Mechanics*, September 2002 Edition, BlackLight Power, Inc., Cranbury, New Jersey, (" '02 Mills GUT"), provided by BlackLight Power, Inc., 493 Old Trenton Road, Cranbury, NJ, 08512 (posted at www.blacklightpower.com; R. Mills, P. Ray, R. M. Mayo, "Comparison of Ammonia-Plasma Sources of Stationary Inverted Balmer and Lyman Populations for a CW HI Laser", J. Appl. Spectroscopy, in preparation; R. L. Mills, P. C. Ray, B. Dhandapani, R. M. Mayo, J. He, A. Echezuria, M. Nansteel, X Chen, "Excessive Balmer α Line Broadening of Glow Discharge and Microwave Hydrogen Plasmas, Excess Power, and a Novel Vibrational Series in the EUV Region Due to a Catalytic Reaction of Atomic Hydrogen", IJHE, in preparation; R. L. Mills, P. Ray, J. Dong, M. Nansteel, R. M. Mayo, B. Dhandapani, X. Chen, "Comparison of Balmer α Line Broadening and Power Balances of Helium-Hydrogen Plasma Sources", IJHE, in preparation; R. Mills, P. Ray, M. Nansteel, R. M. Mayo, "Comparison of Water-Plasma Sources of Stationary Inverted Balmer and Lyman Populations for a CW HI Laser", J. Appl. Spectroscopy, in preparation; R. Mills, J. He, B. Dhandapani, P. Ray, "Comparison of Catalysts and Microwave Plasma Sources of Vibrational Spectral Emission of Fractional-Rydberg-State Hydrogen Molecular Ion", Canadian Journal of Physics, submitted; R. L. Mills, P. Ray, J. Dong, M. Nansteel, B. Dhandapani, J. He, "Vibrational Spectral Emission of Fractional-Principal-Quantum-Energy-Level Molecular Hydrogen", Bulletin of the Chemical Society of Japan, submitted; J. Phillips, R. L. Mills, X. Chen, "Water Bath Calorimetric Study of Excess Heat in 'Resonance Transfer' Plasmas", Journal of Applied Physics, submitted; R. L. Mills, P. Ray, B. Dhandapani, X. Chen, "Comparison of Catalysts and Microwave Plasma Sources of Spectral Emission of Fractional-Principal-Quantum-Energy-Level Atomic and Molecular Hydrogen", Journal of Applied Spectroscopy, submitted; R. Mills, J. He, A. Echezuria, B Dhandapani, P. Ray, "Comparison of Catalysts and Microwave Plasma Sources of Vibrational Spectral Emission of Fractional-Rydberg-State Hydrogen Molecular Ion", Vibrational Spectroscopy, submitted; R. L. Mills, P. Ray, B. Dhandapani, J. He, "Novel Liquid-Nitrogen-Condensable Molecular Hydrogen Gas", Chemistry—A European Journal, submitted; R. L. Mills, P. C. Ray, R. M. Mayo, M. Nansteel, B. Dhandapani, J. Phillips, "Spectroscopic Study of Unique Line Broadening and Inversion in Low Pressure Microwave Generated Water Plasmas", Physics of Plasmas, submitted; R. L.

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1999; Ser. No. 60/095,149, filed August 3, 1998; Ser. No. 60/101,651, filed September 24, 1998; Ser. No. 60/105,752, filed October 26, 1998; Ser. No. 60/113,713, filed December 24, 1998; Ser. No. 60/123,835, filed March 11, 1999; Ser. No. 60/130,491, filed April 22, 1999; Ser. No. 60/141,036, filed June 29, 1999; Serial No. 09/009,294 filed January 20, 1998; Serial No. 09/111,160 filed July 7, 1998; Serial No. 09/111,170 filed July 7, 1998; Serial No. 09/111,016 filed July 7, 1998; Serial No. 09/111,003 filed July 7, 1998; Serial No. 09/110,694 filed July 7, 1998; Serial No. 09/110,717 filed July 7, 1998; Serial No. 60/053378 filed July 22, 1997; Serial No. 60/068913 filed December 29, 1997; Serial No. 60/090239 filed June 22, 1998; Serial No. 09/009455 filed January 20, 1998; Serial No. 09/110,678 filed July 7, 1998; Serial No. 60/053,307 filed July 22, 1997; Serial No. 60/068918 filed December 29, 1997; Serial No. 60/080,725 filed April 3, 1998; Serial No. 09/181,180 filed October 28, 1998; Serial No. 60/063,451 filed October 29, 1997; Serial No. 09/008,947 filed January 20, 1998; Serial No. 60/074,006 filed February 9, 1998; Serial No. 60/080,647 filed April 3, 1998; Serial No. 09/009,837 filed January 20, 1998; Serial No. 08/822,170 filed March 27, 1997; Serial No. 08/592,712 filed January 26, 1996; Serial No. 08/467,051 filed on June 6, 1995; Serial No. 08/416,040 filed on April 3, 1995; Serial No. 08/467,911 filed on June 6, 1995; Serial No. 08/107,357 filed on August 16, 1993; Serial No. 08/075,102 filed on June 11, 1993; Serial No. 07/626,496 filed on December 12,1990; Serial No. 07/345,628 filed April 28, 1989; Serial No. 07/341,733 filed April 21, 1989 the entire disclosures of which are all incorporated herein by reference (hereinafter "Mills Prior Publications").

The binding energy of an atom, ion, or molecule, also known as the ionization energy, is the energy required to remove one electron from the atom, ion or molecule. A hydrogen atom having the binding energy given in Eq. (1) is hereafter referred to as a hydrino atom or hydrino. The designation for a hydrino of radius $\frac{a_H}{p}$, where a_H is the radius of an ordinary hydrogen atom and p is an integer, is $H\left[\frac{a_H}{p}\right]$. A hydrogen atom with a radius a_H is hereinafter referred to as "ordinary hydrogen atom" or "normal hydrogen atom." Ordinary atomic hydrogen is characterized by its binding energy of 13.6 eV.

Hydrinos are formed by reacting an ordinary hydrogen atom with a catalyst having a net enthalpy of reaction of about

$$m \cdot 27.2\ eV \tag{2a}$$

where m is an integer. This catalyst has also been referred to as an energy hole or source of energy hole in Mills earlier filed Patent Applications. It is believed that the rate of catalysis is

increased as the net enthalpy of reaction is more closely matched to $m \cdot 27.2\ eV$. It has been found that catalysts having a net enthalpy of reaction within ±10%, preferably ±5%, of $m \cdot 27.2\ eV$ are suitable for most applications.

In another embodiment, the catalyst to form hydrinos has a net enthalpy of reaction of about

$$m/2 \cdot 27.2\ eV \qquad (2b)$$

where m is an integer greater that one. It is believed that the rate of catalysis is increased as the net enthalpy of reaction is more closely matched to $m/2 \cdot 27.2\ eV$. It has been found that catalysts having a net enthalpy of reaction within ±10%, preferably ±5%, of $m/2 \cdot 27.2\ eV$ are suitable for most applications.

A catalyst of the present invention may provide a net enthalpy of $m \cdot 27.2\ eV$ where m is an integer or $m/2 \cdot 27.2\ eV$ where m is an integer greater than one by undergoing a transition to a resonant excited state energy level with the energy transfer from hydrogen. For example, He^+ absorbs $40.8\ eV$ during the transition from the $n = 1$ energy level to the $n = 2$ energy level which corresponds to $3/2 \cdot 27.2\ eV$ ($m = 3$ in Eq. (2b)). This energy is resonant with the difference in energy between the $p = 2$ and the $p = 1$ states of atomic hydrogen given by Eq. (1). Thus He^+ may serve as a catalyst to cause the transition between these hydrogen states.

A catalyst of the present invention may provide a net enthalpy of $m \cdot 27.2\ eV$ where m is an integer or $m/2 \cdot 27.2\ eV$ where m is an integer greater than one by becoming ionized during resonant energy transfer. For example, the third ionization energy of argon is $40.74\ eV$; thus, Ar^{2+} absorbs $40.8\ eV$ during the ionization to Ar^{3+} which corresponds to $3/2 \cdot 27.2\ eV$ ($m = 3$ in Eq. (2b)). This energy is resonant with the difference in energy between the $p = 2$ and the $p = 1$ states of atomic hydrogen given by Eq. (1). Thus Ar^{2+} may serve as a catalyst to cause the transition between these hydrogen states.

This catalysis releases energy from the hydrogen atom with a commensurate decrease in size of the hydrogen atom, $r_n = n a_H$. For example, the catalysis of $H(n = 1)$ to $H(n = 1/2)$ releases $40.8\ eV$, and the hydrogen radius decreases from a_H to $\frac{1}{2} a_H$. A catalytic system is provided by the ionization of t electrons from an atom each to a continuum energy level such that the sum of the ionization energies of the t electrons is approximately $m \times 27.2\ eV$ where m is an integer. One such catalytic system involves potassium metal. The first, second, and third ionization energies of potassium are $4.34066\ eV$, $31.63\ eV$, $45.806\ eV$, respectively [D.

R. Lide, CRC Handbook of Chemistry and Physics, 78 th Edition, CRC Press, Boca Raton, Florida, (1997), p. 10-214 to 10-216]. The triple ionization ($t = 3$) reaction of K to K^{3+}, then, has a net enthalpy of reaction of 81.7426 eV, which is equivalent to $m = 3$ in Eq. (2a).

$$81.7426\ eV + K(m) + H\left[\frac{a_H}{p}\right] \rightarrow K^{3+} + 3e^- + H\left[\frac{a_H}{(p+3)}\right] + [(p+3)^2 - p^2]X13.6\ eV \quad (3)$$

$$K^{3+} + 3e^- \rightarrow K(m) + 81.7426\ eV \quad (4)$$

And, the overall reaction is

$$H\left[\frac{a_H}{p}\right] \rightarrow H\left[\frac{a_H}{(p+3)}\right] + [(p+3)^2 - p^2]X13.6\ eV \quad (5)$$

Rubidium ion (Rb^+) is also a catalyst because the second ionization energy of rubidium is 27.28 eV. In this case, the catalysis reaction is

$$27.28\ eV + Rb^+ + H\left[\frac{a_H}{p}\right] \rightarrow Rb^{2+} + e^- + H\left[\frac{a_H}{(p+1)}\right] + [(p+1)^2 - p^2]X13.6\ eV \quad (6)$$

$$Rb^{2+} + e^- \rightarrow Rb^+ + 27.28\ eV \quad (7)$$

And, the overall reaction is

$$H\left[\frac{a_H}{p}\right] \rightarrow H\left[\frac{a_H}{(p+1)}\right] + [(p+1)^2 - p^2]X13.6\ eV \quad (8)$$

Strontium ion (Sr^+) is also a catalyst since the second and third ionization energies of strontium are 11.03013 eV and 42.89 eV, respectively. The ionization reaction of Sr^+ to Sr^{3+}, ($t = 2$), then, has a net enthalpy of reaction of 53.92 eV, which is equivalent to $m = 2$ in Eq. (2a).

$$53.92\ eV + Sr^+ + H\left[\frac{a_H}{p}\right] \rightarrow Sr^{3+} + 2e^- + H\left[\frac{a_H}{(p+2)}\right] + [(p+2)^2 - p^2]X13.6\ eV \quad (9)$$

$$Sr^{3+} + 2e^- \rightarrow Sr^+ + 53.92\ eV \quad (10)$$

And, the overall reaction is

$$H\left[\frac{a_H}{p}\right] \rightarrow H\left[\frac{a_H}{(p+2)}\right] + [(p+2)^2 - p^2]X13.6\ eV \quad (11)$$

Helium ion (He^+) is also a catalyst because the second ionization energy of helium is 54.417 eV. In this case, the catalysis reaction is

$$54.417\ eV + He^{+} + H\left[\frac{a_H}{p}\right] \rightarrow He^{2+} + e^{-} + H\left[\frac{a_H}{(p+2)}\right] + [(p+2)^2 - p^2]X13.6\ eV \quad (12)$$

$$He^{2+} + e^{-} \rightarrow He^{+} + 54.417\ eV \quad (13)$$

And, the overall reaction is

$$H\left[\frac{a_H}{p}\right] \rightarrow H\left[\frac{a_H}{(p+2)}\right] + [(p+2)^2 - p^2]X13.6\ eV \quad (14)$$

Argon ion is a catalyst. The second ionization energy is $27.63\ eV$.

$$27.63\ eV + Ar^{+} + H\left[\frac{a_H}{p}\right] \rightarrow Ar^{2+} + e^{-} + H\left[\frac{a_H}{(p+1)}\right] + [(p+1)^2 - p^2]X13.6\ eV \quad (15)$$

$$Ar^{2+} + e^{-} \rightarrow Ar^{+} + 27.63\ eV \quad (16)$$

And, the overall reaction is

$$H\left[\frac{a_H}{p}\right] \rightarrow H\left[\frac{a_H}{(p+1)}\right] + [(p+1)^2 - p^2]X13.6\ eV \quad (17)$$

A neon ion and a proton can also provide a net enthalpy of a multiple of that of the potential energy of the hydrogen atom. The second ionization energy of neon is $40.96\ eV$, and H^{+} releases $13.6\ eV$ when it is reduced to H. The combination of reactions of Ne^{+} to Ne^{2+} and H^{+} to H, then, has a net enthalpy of reaction of $27.36\ eV$, which is equivalent to $m = 1$ in Eq. (2a).

$$27.36\ eV + Ne^{+} + H^{+} + H\left[\frac{a_H}{p}\right] \rightarrow H + Ne^{2+} + H\left[\frac{a_H}{(p+1)}\right] + [(p+1)^2 - p^2]X13.6\ eV \quad (18)$$

$$H + Ne^{2+} \rightarrow H^{+} + Ne^{+} + 27.36\ eV \quad (19)$$

And, the overall reaction is

$$H\left[\frac{a_H}{p}\right] \rightarrow H\left[\frac{a_H}{(p+1)}\right] + [(p+1)^2 - p^2]X13.6\ eV \quad (20)$$

A neon ion can also provide a net enthalpy of a multiple of that of the potential energy of the hydrogen atom. Ne^{+} has an excited state Ne^{+*} of $27.2\ eV$ ($46.5\ nm$) which provides a net enthalpy of reaction of $27.2\ eV$, which is equivalent to $m = 1$ in Eq. (2a).

$$27.2\ eV + Ne^{+} + H\left[\frac{a_H}{p}\right] \rightarrow Ne^{+*} + H\left[\frac{a_H}{(p+1)}\right] + [(p+1)^2 - p^2]X13.6\ eV \quad (21)$$

$$Ne^{+*} \rightarrow Ne^{+} + 27.2\ eV \quad (22)$$

And, the overall reaction is

$$H\left[\frac{a_H}{p}\right] \rightarrow H\left[\frac{a_H}{(p+1)}\right] + [(p+1)^2 - p^2]X13.6\,eV \quad (23)$$

The first neon excimer continuum Ne_2^* may also provide a net enthalpy of a multiple of that of the potential energy of the hydrogen atom. The first ionization energy of neon is 21.56454 eV, and the first neon excimer continuum Ne_2^* has an excited state energy of 15.92 eV. The combination of reactions of Ne_2^* to $2Ne^+$, then, has a net enthalpy of reaction of 27.21 eV, which is equivalent to $m = 1$ in Eq. (2a).

$$27.21\,eV + Ne_2^* + H\left[\frac{a_H}{p}\right] \rightarrow 2Ne^+ + H\left[\frac{a_H}{(p+1)}\right] + [(p+1)^2 - p^2]X13.6\,eV \quad (24)$$

$$2Ne^+ \rightarrow Ne_2^* + 27.21\,eV \quad (25)$$

And, the overall reaction is

$$H\left[\frac{a_H}{p}\right] \rightarrow H\left[\frac{a_H}{(p+1)}\right] + [(p+1)^2 - p^2]X13.6\,eV \quad (26)$$

Similarly for helium, the helium excimer continuum to shorter wavelengths He_2^* may also provide a net enthalpy of a multiple of that of the potential energy of the hydrogen atom. The first ionization energy of helium is 24.58741 eV, and the helium excimer continuum He_2^* has an excited state energy of 21.97 eV. The combination of reactions of He_2^* to $2He^+$, then, has a net enthalpy of reaction of 27.21 eV, which is equivalent to $m = 1$ in Eq. (2a).

$$27.21\,eV + He_2^* + H\left[\frac{a_H}{p}\right] \rightarrow 2He^+ + H\left[\frac{a_H}{(p+1)}\right] + [(p+1)^2 - p^2]X13.6\,eV \quad (27)$$

$$2He^+ \rightarrow He_2^* + 27.21\,eV \quad (28)$$

And, the overall reaction is

$$H\left[\frac{a_H}{p}\right] \rightarrow H\left[\frac{a_H}{(p+1)}\right] + [(p+1)^2 - p^2]X13.6\,eV \quad (29)$$

Atomic hydrogen in sufficient concentration may serve as a catalyst since the ionization energy of hydrogen is 13.6 eV. Two atoms fulfill the catalyst criterion—a chemical or physical process with an enthalpy change equal to an integer multiple of 27.2 eV since together they ionize at 27.2 eV. Thus, the transition cascade for the pth cycle of the hydrogen-type atom, $H\left[\frac{a_H}{p}\right]$, with two hydrogen atoms, $H\left[\frac{a_H}{1}\right]$, as the catalyst is represented by

$$27.21\,eV + 2H\left[\frac{a_H}{1}\right] + H\left[\frac{a_H}{p}\right] \rightarrow 2H^+ + 2e^- + H\left[\frac{a_H}{(p+1)}\right] + [(p+1)^2 - p^2]X13.6\,eV \quad (30)$$

a net enthalpy of reaction of 53.9 eV, which is equivalent to $m = 2$ in Eq. (2a).

$$53.9\ eV + O_2 + H\left[\frac{a_H}{p}\right] \rightarrow O + O^{2+} + H\left[\frac{a_H}{(p+2)}\right] + [(p+2)^2 - p^2]X13.6\ eV \quad (39)$$

$$O + O^{2+} \rightarrow O_2 + 53.9\ eV \quad (40)$$

And, the overall reaction is

$$H\left[\frac{a_H}{p}\right] \rightarrow H\left[\frac{a_H}{(p+2)}\right] + [(p+2)^2 - p^2]X13.6\ eV \quad (41)$$

An oxygen molecule can also provide a net enthalpy of a multiple of that of the potential energy of the hydrogen atom by an alternative reaction. The bond energy of the oxygen molecule is 5.165 eV, and the first through the third ionization energies of an oxygen atom are 13.61806 eV, 35.11730 eV, and 54.9355 eV, respectively. The combination of reactions of O_2 to $2O$ and O to O^{3+}, then, has a net enthalpy of reaction of 108.83 eV, which is equivalent to $m = 4$ in Eq. (2a).

$$108.83\ eV + O_2 + H\left[\frac{a_H}{p}\right] \rightarrow O + O^{3+} + H\left[\frac{a_H}{(p+4)}\right] + [(p+4)^2 - p^2]X13.6\ eV \quad (42)$$

$$O + O^{3+} \rightarrow O_2 + 108.83\ eV \quad (43)$$

And, the overall reaction is

$$H\left[\frac{a_H}{p}\right] \rightarrow H\left[\frac{a_H}{(p+4)}\right] + [(p+4)^2 - p^2]X13.6\ eV \quad (44)$$

An oxygen molecule can also provide a net enthalpy of a multiple of that of the potential energy of the hydrogen atom by an alternative reaction. The bond energy of the oxygen molecule is 5.165 eV, and the first through the fifth ionization energies of an oxygen atom are 13.61806 eV, 35.11730 eV, 54.9355 eV, 77.41353 eV, and 113.899 eV, respectively. The combination of reactions of O_2 to $2O$ and O to O^{5+}, then, has a net enthalpy of reaction of 300.15 eV, which is equivalent to $m = 11$ in Eq. (2a).

$$300.15\ eV + O_2 + H\left[\frac{a_H}{p}\right] \rightarrow O + O^{5+} + H\left[\frac{a_H}{(p+11)}\right] + [(p+11)^2 - p^2]X13.6\ eV \quad (45)$$

$$O + O^{5+} \rightarrow O_2 + 300.15\ eV \quad (46)$$

And, the overall reaction is

$$H\left[\frac{a_H}{p}\right] \rightarrow H\left[\frac{a_H}{(p+11)}\right] + [(p+11)^2 - p^2]X13.6\ eV \quad (47)$$

$$2H^{+} + 2e^{-} \rightarrow 2H\left[\frac{a_H}{1}\right] + 27.21\ eV \quad (31)$$

And, the overall reaction is

$$H\left[\frac{a_H}{p}\right] \rightarrow H\left[\frac{a_H}{(p+1)}\right] + [(p+1)^2 - p]X13.6\ eV \quad (32)$$

A nitrogen molecule can also provide a net enthalpy of a multiple of that of the potential energy of the hydrogen atom. The bond energy of the nitrogen molecule is 9.75 eV, and the first and second ionization energies of the nitrogen atom are 14.53414 eV and 29.6013 eV, respectively. The combination of reactions of N_2 to $2N$ and N to N^{2+}, then, has a net enthalpy of reaction of 53.9 eV, which is equivalent to $m = 2$ in Eq. (2a).

$$53.9\ eV + N_2 + H\left[\frac{a_H}{p}\right] \rightarrow N + N^{2+} + H\left[\frac{a_H}{(p+2)}\right] + [(p+2)^2 - p^2]X13.6\ eV \quad (33)$$

$$N + N^{2+} \rightarrow N_2 + 53.9\ eV \quad (34)$$

And, the overall reaction is

$$H\left[\frac{a_H}{p}\right] \rightarrow H\left[\frac{a_H}{(p+2)}\right] + [(p+2)^2 - p^2]X13.6\ eV \quad (35)$$

A carbon molecule can also provide a net enthalpy of a multiple of that of the potential energy of the hydrogen atom. The bond energy of the carbon molecule is 6.29 eV, and the first and through the sixth ionization energies of a carbon atom are 11.2603 eV, 24.38332 eV, 47.8878 eV, 64.4939 eV, and 392.087 eV, respectively. The combination of reactions of C_2 to $2C$ and C to C^{5+}, then, has a net enthalpy of reaction of 546.40232 eV, which is equivalent to $m = 20$ in Eq. (2a).

$$546.4\ eV + C_2 + H\left[\frac{a_H}{p}\right] \rightarrow C + C^{5+} + H\left[\frac{a_H}{(p+20)}\right] + [(p+20)^2 - p^2]X13.6\ eV \quad (36)$$

$$C + C^{5+} \rightarrow C_2 + 546.4\ eV \quad (37)$$

And, the overall reaction is

$$H\left[\frac{a_H}{p}\right] \rightarrow H\left[\frac{a_H}{(p+20)}\right] + [(p+20)^2 - p^2]X13.6\ eV \quad (38)$$

An oxygen molecule can also provide a net enthalpy of a multiple of that of the potential energy of the hydrogen atom. The bond energy of the oxygen molecule is 5.165 eV, and the first and second ionization energies of an oxygen atom are 13.61806 eV and 35.11730 eV, respectively. The combination of reactions of O_2 to $2O$ and O to O^{2+}, then, has

In addition to nitrogen, carbon, and oxygen molecules which are exemplary catalysts, other molecules may be catalysts according to the present invention wherein the energy to break the molecular bond and the ionization of t electrons from an atom from the dissociated molecule to a continuum energy level is such that the sum of the ionization energies of the t electrons is approximately $m \cdot 27.2\ eV$ where t and m are each an integer. The bond energies and the ionization energies may be found in standard sources such as D. R. Linde, CRC Handbook of Chemistry and Physics, 79 th Edition, CRC Press, Boca Raton, Florida, (1999), p. 9-51 to 9-69 and David R. Linde, CRC Handbook of Chemistry and Physics, 79 th Edition, CRC Press, Boca Raton, Florida, (1998-9), p. 10-175 to p. 10-177, respectively. Thus, further molecular catalysts which provide a positive enthalpy of $m \cdot 27.2\ eV$ to cause release of energy from atomic hydrogen may be determined by one skilled in the art.

Molecular hydrogen catalysts capable of providing a net enthalpy of reaction of approximately $m \times 27.2\ eV$ where m is an integer to produce hydrino whereby the molecular bond is broken and t electrons are ionized from a corresponding free atom of the molecule are given *infra*. The bonds of the molecules given in the first column are broken and the atom also given in the first column is ionized to provide the net enthalpy of reaction of $m \times 27.2\ eV$ given in the eleventh column where m is given in the twelfth column. The energy of the bond which is broken given by Linde [D. R. Lide, CRC Handbook of Chemistry and Physics, 79 th Edition, CRC Press, Boca Raton, Florida, (1999), p. 9-51 to 9-69] which is herein incorporated by reference is given in the 2nd column, and the electrons which are ionized are given with the ionization potential (also called ionization energy or binding energy). The ionization potential of the n th electron of the atom or ion is designated by IP_n and is given by Linde [D. R. Lide, CRC Handbook of Chemistry and Physics, 79 th Edition, CRC Press, Boca Raton, Florida, (1998-9), p. 10-175 to p. 10-177] which is herein incorporated by reference. For example, the bond energy of the oxygen molecule, $BE = 5.165\ eV$, is given in the 2nd column, and the first ionization potential, $IP_1 = 13.61806\ eV$, and the second ionization potential, $IP_2 = 35.11730\ eV$, are given in the third and fourth columns, respectively. The combination of reactions of O_2 to $2O$ and O to O^{2+}, then, has a net enthalpy of reaction of $53.9\ eV$, as given in the eleventh column, and $m = 2$ in Eq. (2a) as given in the twelfth column.

TABLE 1. Molecular Hydrogen Catalysts

Catalyst	BE	IP1	IP2	IP3	IP4	IP5	IP6	IP7	IP8	Enthalpy	m
C_2/C	6.26	11.26	24.38	47.86	64.49	392.0				546.4	20
		03	332	78	39	87					
N_2/N	9.75	14.53	29.60							53.9	2
		414	13								
O_2/O	5.165	13.61	35.11							54.26	2
		806	730								
O_2/O	5.165	13.61	35.11	54.93						108.83	4
		806	730	55							
O_2/O	5.165	13.61	35.11	54.93	77.41	113.8				300.15	11
		806	730	55	353	99					
CO_2/O	5.52	13.61	35.11							54.26	2
		806	730								
CO_2/O	5.52	13.61	35.11	54.93						109.19	4
		806	730	55							
CO_2/O	5.52	13.61	35.11	54.93	77.41	113.8				300.5	11
		806	730	55	353	990					
NO_2/O	3.16	13.61	35.11	54.93	77.41	113.8				298.14	11
		806	730	55	353	990					
NO_3/O	2.16	13.61	35.11	54.93	77.41	113.8	138.1			435.26	16
		806	730	55	353	990	197				

In an embodiment, a molecular catalyst such as nitrogen is combined with another catalyst such as He^+ (Eqs. (12-14)) or Ar^+ (Eqs. (15-17)). In an embodiment of a catalyst combination of argon and nitrogen, the percentage of nitrogen is within the range 1-10%. In an embodiment of a catalyst combination of argon and nitrogen, the source of hydrogen atoms is a hydrogen halide such as HF.

The energy given off during catalysis is much greater than the energy lost to the catalyst. The energy released is large as compared to conventional chemical reactions. For example, when hydrogen and oxygen gases undergo combustion to form water

$$H_2(g) + \frac{1}{2}O_2(g) \rightarrow H_2O(l) \tag{48}$$

the known enthalpy of formation of water is $\Delta H_f = -286\ kJ/mole$ or 1.48 eV per hydrogen atom. By contrast, each ($n = 1$) ordinary hydrogen atom undergoing catalysis releases a net of 40.8 eV. Moreover, further catalytic transitions may occur: $n = \frac{1}{2} \rightarrow \frac{1}{3}$, $\frac{1}{3} \rightarrow \frac{1}{4}$, $\frac{1}{4} \rightarrow \frac{1}{5}$, and so on. Once catalysis begins, hydrinos autocatalyze further in a process called disproportionation. This mechanism is similar to that of an inorganic ion catalysis. But,

hydrino catalysis should have a higher reaction rate than that of the inorganic ion catalyst due to the better match of the enthalpy to $m \cdot 27.2\ eV$.

2.2 Dihydrino Molecular Ion, Dihydrino Molecule, and Hydrino Hydride Ion

The theory of lower-energy hydrogen molecular ions, molecules, and hydride ions are given in Mills '02 GUT in Chps. 12 and 7 which are incorporated by reference. $H(1/p)$ may react with a proton to form a molecular ion $H_2(1/p)^+$ that has a bond energy and vibrational levels that are p^2 times those of the molecular ion comprising uncatalyzed atomic hydrogen where p is an integer. E_T, the total energy of the hydrogen molecular $H_2(1/p)^+$, is

$$E_T = 13.6\ eV(-4p^2 \ln 3 + p^2 + 2p^2 \ln 3) = -p^2 16.28\ eV \tag{49}$$

The bond dissociation energy, E_D, is the difference between the total energy of the corresponding hydrogen atom or hydrino atom and E_T.

$$E_D = E(H\left[\frac{a_H}{p}\right]) - E_T = -p^2 13.6 + p^2 16.28\ eV = p^2 2.68\ eV \tag{50}$$

$H_2(1/p)^+$ has been observed spectroscopically [R. Mills, P. Ray, "Vibrational Spectral Emission of Fractional-Principal-Quantum-Energy-Level Hydrogen Molecular Ion", Int. J. Hydrogen Energy, Vol. 27, No. 5, (2002), pp. 533-564; R. Mills, J. He, A. Echezuria, B Dhandapani, P. Ray, "Comparison of Catalysts and Plasma Sources of Vibrational Spectral Emission of Fractional-Rydberg-State Hydrogen Molecular Ion", Vibrational Spectroscopy, submitted]. For example, the catalysis reaction product $H(1/4)$ was predicted to further react to form a new molecular ion $H_2(1/4)^+$ with the emission of a vibrational series from its transition state. The emission including both Stokes and antiStokes-like branches is given by the previously derived formula [R. Mills, J. He, A. Echezuria, B Dhandapani, P. Ray, "Comparison of Catalysts and Plasma Sources of Vibrational Spectral Emission of Fractional-Rydberg-State Hydrogen Molecular Ion", Vibrational Spectroscopy, submitted]:

$$E_{D+vib} = 4^2 E_{D\,H_2^+} \pm \upsilon^* 2^2 E_{vib\,H_2^+(\upsilon=0\to\upsilon=1)},\quad \upsilon^* = 0,1,2,3... \tag{51}$$

In Eq. (51), $E_{D\,H_2^+}$ and $E_{vib\,H_2^+(\upsilon=0\to\upsilon=1)}$ are the experimental bond and vibrational energies of H_2^+, respectively. Extreme ultraviolet (EUV) spectroscopy was recorded on microwave discharges of helium with 10% hydrogen in the range 10-65 nm. The predicted emission (Eq. (51)) was observed at the longer wavelengths for $\upsilon^* = 0$ to $\upsilon^* = 20$ and at the shorter wavelengths for $\upsilon^* = 0$ to $\upsilon^* = 3$. A peak at 28.93 nm matched the predicted bond energy of the molecular ion, 42.88 eV.

The diatomic molecule $H_2(1/p)$ may form by reaction of the corresponding fractional Rydberg state atoms $H(1/p)$

$$2H(1/p) \rightarrow H_2(1/p) \quad (52)$$

where each energy level corresponds to a fractional quantum number that is the reciprocal of an integer p. The central field of fractional Rydberg state $H_2(1/p)$ is p times that of ordinary H_2, the corresponding total, bond, and vibrational energies are p^2 those of H_2, and the internuclear distance is

$$2c' = \frac{\sqrt{2}a_o}{p} \quad (53)$$

E_T, the total energy of the molecule $H_2(1/p)$, is

$$E_T = -13.6\,eV\left[\left(2p^2\sqrt{2} - p^2\sqrt{2} + \frac{p^2\sqrt{2}}{2}\right)\ln\frac{\sqrt{2}+1}{\sqrt{2}-1} - p^2\sqrt{2}\right] = -p^2 31.63\,eV \quad (54)$$

where $-31.63\,eV$ is the total energy of H_2. The experimental bond energy of the hydrogen molecule [P. W. Atkins, *Physical Chemistry*, Second Edition, W. H. Freeman, San Francisco, (1982), p. 589] is

$$E_D = 4.4783\,eV \quad (55)$$

The theoretical bond energies of hydrogen type-type molecules $H_2(1/p)$ are

$$E_D = p^2 4.4783\,eV \quad (56)$$

Dihydrino gas has been cryogenically isolated [. L. Mills, P. Ray, B. Dhandapani, J. He, "Novel Liquid-Nitrogen-Condensable Molecular Hydrogen Gas", Chemistry—A European Journal, submitted which is herein incorporated by reference in its entirety]. Extreme ultraviolet (EUV) spectroscopy was recorded on microwave discharges of helium with 2% hydrogen. Novel emission lines were observed with energies of $q \cdot 13.6\,eV$ where $q = 1,2,3,4,6,7,8,9,11$ or these discrete energies less $21.2\,eV$ corresponding to inelastic scattering of these photons by helium atoms due to excitation of $He(1s^2)$ to $He(1s^1 2p^1)$. These lines matched $H(1/p)$, fractional Rydberg states of atomic hydrogen, formed by a resonant nonradiative energy transfer to He^+. Corresponding emission due to the reaction $2H(1/2) \rightarrow H_2(1/2)$ with vibronic coupling at $E_{D+vib} = p^2 E_{D\,H_2} \pm \left(\frac{\upsilon^*}{3}\right) E_{vib\,H_2(\upsilon=0\rightarrow\upsilon=1)}$, $\upsilon^* = 1,2,3...$ was observed at the longer wavelengths for $\upsilon^* = 2$ to $\upsilon^* = 32$ and at the shorter wavelengths for $\upsilon^* = 1$ to $\upsilon^* = 16$ where $E_{D\,H_2}$ and $E_{vib\,H_2(\upsilon=0\rightarrow\upsilon=1)}$ are the experimental bond and vibrational energies of H_2, respectively. Fraction-principal-quantum-level molecular

hydrogen $H_2(1/p)$ gas was isolated by liquefaction using an ultrahigh-vacuum liquid nitrogen cryotrap and was characterized by gas chromatography (GC), mass spectroscopy (MS), optical emission spectroscopy (OES), and ^1H NMR of the condensable gas dissolved in $CDCl_3$. The condensable gas was highly pure hydrogen by GC and MS and had a higher ionization energy than H_2. In addition to the Balmer series, a unique visible emission spectrum was observed by OES that shifted with deuterium substitution. An upfield shifted NMR peak was observed at 3.25 ppm compared to that of H_2 at 4.63 ppm.

The hydrino hydride ion of the present invention can be formed by the reaction of an electron source with a hydrino, that is, a hydrogen atom having a binding energy of about $\frac{13.6\ eV}{n^2}$, where $n=\frac{1}{p}$ and p is an integer greater than 1. The hydrino hydride ion is represented by $H^-(n=1/p)$ or $H^-(1/p)$:

$$H\left[\frac{a_H}{p}\right]+e^- \rightarrow H^-(n=1/p) \tag{57a}$$

$$H\left[\frac{a_H}{p}\right]+e^- \rightarrow H^-(1/p) \tag{57b}$$

The hydrino hydride ion is distinguished from an ordinary hydride ion comprising an ordinary hydrogen nucleus and two electrons having a binding energy of about 0.8 eV. The latter is hereafter referred to as "ordinary hydride ion" or "normal hydride ion" The hydrino hydride ion comprises a hydrogen nucleus including proteum, deuterium, or tritium, and two indistinguishable electrons at a binding energy according to Eq. (58).

The binding energy of a novel hydrino hydride ion can be represented by the following formula:

$$Binding\ Energy=\frac{\hbar^2\sqrt{s(s+1)}}{8\mu_e a_0^2\left[\frac{1+\sqrt{s(s+1)}}{p}\right]^2}-\frac{\pi\mu_0 e^2\hbar^2}{m_e^2}\left(\frac{1}{a_H^3}+\frac{2^2}{a_0^3\left[\frac{1+\sqrt{s(s+1)}}{p}\right]^3}\right) \tag{58}$$

where p is an integer greater than one, $s=1/2$, π is pi, $\hbar$ is Planck's constant bar, μ_o is the permeability of vacuum, m_e is the mass of the electron, μ_e is the reduced electron mass given by $\mu_e=\frac{m_e m_p}{\sqrt{\frac{3}{4}}m_e+m_p}$ where m_p is the mass of the proton, a_H is the radius of the hydrogen atom, a_o is the Bohr radius, and e is the elementary charge. The radii are given by

$$r_2 = r_1 = a_0\left(1+\sqrt{s(s+1)}\right)\ s=\frac{1}{2} \tag{59}$$

The binding energies of the hydrino hydride ion, $H^-(n=1/p)$ as a function of p, where p is an integer, are shown in TABLE 2.

TABLE 2. The representative binding energy of the hydrino hydride ion $H^-(n=1/p)$ as a function of p, Eq. (58).

Hydride Ion	r_1 (a_o)[a]	Binding Energy (eV)[b]	Wavelength (nm)
$H^-(n=1)$	1.8660	0.7542	1644
$H^-(n=1/2)$	0.9330	3.047	406.9
$H^-(n=1/3)$	0.6220	6.610	187.6
$H^-(n=1/4)$	0.4665	11.23	110.4
$H^-(n=1/5)$	0.3732	16.70	74.23
$H^-(n=1/6)$	0.3110	22.81	54.35
$H^-(n=1/7)$	0.2666	29.34	42.25
$H^-(n=1/8)$	0.2333	36.09	34.46
$H^-(n=1/9)$	0.2073	42.84	28.94
$H^-(n=1/10)$	0.1866	49.38	25.11
$H^-(n=1/11)$	0.1696	55.50	22.34
$H^-(n=1/12)$	0.1555	60.98	20.33
$H^-(n=1/13)$	0.1435	65.63	18.89
$H^-(n=1/14)$	0.1333	69.22	17.91
$H^-(n=1/15)$	0.1244	71.55	17.33
$H^-(n=1/16)$	0.1166	72.40	17.12
$H^-(n=1/17)$	0.1098	71.56	17.33
$H^-(n=1/18)$	0.1037	68.83	18.01
$H^-(n=1/19)$	0.0982	63.98	19.38
$H^-(n=1/20)$	0.0933	56.81	21.82
$H^-(n=1/21)$	0.0889	47.11	26.32
$H^-(n=1/22)$	0.0848	34.66	35.76
$H^-(n=1/23)$	0.0811	19.26	64.36
$H^-(n=1/24)$	0.0778	0.6945	1785

a Equation (59)

b Equation (58)

The existence of novel alkaline and alkaline earth hydride and halido-hydrides were also previously identified by large distinct upfield ^1H NMR resonances compared to the NMR peaks of the corresponding ordinary hydrides [R. Mills, B. Dhandapani, M. Nansteel, J. He, T. Shannon, A. Echezuria, "Synthesis and Characterization of Novel Hydride Compounds", Int. J. of Hydrogen Energy, Vol. 26, No. 4, (2001), pp. 339-367; R. Mills, B. Dhandapani, N. Greenig, J. He, "Synthesis and Characterization of Potassium Iodo Hydride", Int. J. of Hydrogen Energy, Vol. 25, Issue 12, December, (2000), pp. 1185-1203; R. Mills, B. Dhandapani, M. Nansteel, J. He, A. Voigt, "Identification of Compounds Containing Novel Hydride Ions by Nuclear Magnetic Resonance Spectroscopy", Int. J. Hydrogen Energy, Vol. 26, No. 9, (2001), pp. 965-979.]. Using a number of analytical techniques such as XPS and time-of-flight-secondary-mass-spectroscopy (ToF-SIMS) as well as NMR, the hydrogen content was assigned to $H^-(1/p)$, novel high-binding-energy hydride ions in stable fractional principal quantum states [R. Mills, B. Dhandapani, M. Nansteel, J. He, T. Shannon, A. Echezuria, "Synthesis and Characterization of Novel Hydride Compounds", Int. J. of Hydrogen Energy, Vol. 26, No. 4, (2001), pp. 339-367; R. Mills, B. Dhandapani, N. Greenig, J. He, "Synthesis and Characterization of Potassium Iodo Hydride", Int. J. of Hydrogen Energy, Vol. 25, Issue 12, December, (2000), pp. 1185-1203; R. L. Mills, B. Dhandapani, J. He, "Highly Stable Amorphous Silicon Hydride", Solar Energy Materials & Solar Cells, submitted]. The synthesis reactions typically involve metal ion catalysts. For example, Rb^+ to Rb^{2+} and $2K^+$ to $K + K^{2+}$ each provide a reaction with a net enthalpy equal to the potential energy of atomic hydrogen. It was reported previously [R. L. Mills, P. Ray, "A Comprehensive Study of Spectra of the Bound-Free Hyperfine Levels of Novel Hydride Ion $H^-(1/2)$, Hydrogen, Nitrogen, and Air", Int. J. Hydrogen Energy, in press] that the presence of these gaseous ions with thermally dissociated hydrogen formed a hydrogen plasma with hydrogen atom energies of 17 and 12 eV respectively, compared to 3 eV for a hydrogen microwave plasma. The energetic catalytic reaction involves a resonance energy transfer between hydrogen atoms and Rb^+ or $2K^+$ to form a very stable novel hydride ion $H^-(1/2)$. Its predicted binding energy of 3.0468 eV was observed by high resolution visible spectroscopy as a continuum threshold at 406.82 nm, and a structured, strong emission peak was observed at 407.1 nm corresponding to the fine structure and hyperfine structure of $H(1/2)$. From the electron g factor, bound-free hyperfine structure lines of $H^-(1/2)$ were predicted with energies E_{HF} given by $E_{HF} = j^2 3.00213\,X\,10^{-5} + 3.0563\ eV$ (j is an integer) as an inverse Rydberg-type series from

3.0563 eV to 3.1012 eV—the hydride binding energy peak with the fine structure plus one and five times the spin-pairing energy, respectively. The high resolution visible plasma emission spectra in the region of 399.5 to 406.0 nm matched the predicted emission lines for $j = 1$ to $j = 39$ with the series edge at 399.63 nm up to 1 part in 10^5.

2.3 Hydrogen Plasma

Developed sources that provide suitable intensity hydrogen plasmas are high voltage discharges, synchrotron devices, inductively coupled plasma generators, and magnetically confined plasmas. In contrast to the high electric fields, power densities, and temperatures of prior sources, an intense hydrogen plasma is generated at low gas temperatures (e.g. $\approx 10^3\ K$) with a very low field (1V/cm) from atomic hydrogen and certain atomized elements or certain gaseous ions which singly or multiply ionize at integer multiples of the potential energy of atomic hydrogen, $m \cdot 27.2\ eV$ [R. Mills, J. Dong, Y. Lu, "Observation of Extreme Ultraviolet Hydrogen Emission from Incandescently Heated Hydrogen Gas with Certain Catalysts", Int. J. Hydrogen Energy, Vol. 25, (2000), pp. 919-943 which is incorporated by reference]. The so-called resonant transfer or rt-plasma of one embodiment of the present invention forms by a resonant energy transfer mechanism involving the species providing a net enthalpy of a multiple of 27.2 eV and atomic hydrogen.

2.4 Blue to Infrared Laser

Inverted Lyman and Balmer populations may permit a continuous wave (cw) laser at blue wavelengths. For the last four decades, scientists from academia and industry have been searching for lasers using hydrogen plasma. However, the generation of population inversion is very difficult. Recombining expanding plasma jets formed by methods such as arcs or pulsed discharges is considered one of the most promising methods of realizing an H I laser. The continuous generation of a hydrogen inverted population in a stationary steady state plasma has not been achieved. The present invention teaches such an inverted population in water vapor, ammonia vapor, and rt-plasmas as the basis of a laser capable of providing laser wavelengths over a broad range from blue to infrared.

2.5. Photon Power to Electricity Conversion

Electricity can be generated from visible and near infrared light using photovoltaic cells. The efficiency can be increased significantly when the band gap of the material matches

the wavelength, and the efficiency also increases with power to very high power levels ($> 500\ W \cdot cm^{-2}$). Photocells of the power converter of the present invention that respond to ultraviolet and extreme ultraviolet light comprise radiation hardened conventional cells. Due to the higher energy of the photons potentially higher efficiency is achievable compared to those that convert lower energy photons. The hardening may be achieved by a protective coating such as a atomic layer of platinum or other noble metal.

II. SUMMARY OF THE INVENTION

An object of the present invention is to generate power and novel hydrogen species and compositions of matter comprising new forms of hydrogen via the catalysis of atomic hydrogen.

Another object of the present invention is to generate a plasma and a source of light such as high energy light, extreme ultraviolet light and ultraviolet light, and energetic particles such as fast hydrogen atoms (fast H) via the catalysis of atomic hydrogen.

Another object of the present invention is to create an inverted population of an energy level of a species such as an atom, molecule, or ion capable of lasing. The inverted population forms due to catalysis of atomic hydrogen to lower-energy states. The present invention further comprises a laser wherein the catalysis cell serves as the laser cavity, and an inverted population is formed due to catalysis.

Another object of the present invention is to cause the energy of the catalysis reaction to be emitted as high intensity light as well as heat ,by forming excited electronic populations such as atomic hydrogen exited populations using a species which transfers or converts energy from the catalysis reaction to form the excited state populations. In one embodiment, the excited state population comprises an inverted population.

Another object of the present invention is to convert photon power to electrical power.

1. Catalysis of Hydrogen to Form Novel Hydrogen Species and Compositions of Matter Comprising New Forms of Hydrogen

The above object and other objectives are achieved by the present invention comprising a power source and hydrogen reactor. The power source and reactor comprises a cell for the catalysis of atomic hydrogen to form novel hydrogen species and compositions of matter comprising new forms of hydrogen. The novel hydrogen compositions of matter comprise:

(a) at least one neutral, positive, or negative hydrogen species (hereinafter "increased binding energy hydrogen species") having a binding energy

(i) greater than the binding energy of the corresponding ordinary hydrogen species, or

(ii) greater than the binding energy of any hydrogen species for which the corresponding ordinary hydrogen species is unstable or is not observed because the ordinary hydrogen species' binding energy is less than thermal energies at ambient conditions (standard temperature and pressure, STP), or is negative; and

(b) at least one other element. The compounds of the invention are hereinafter referred to as "increased binding energy hydrogen compounds".

By "other element" in this context is meant an element other than an increased binding energy hydrogen species. Thus, the other element can be an ordinary hydrogen species, or any element other than hydrogen. In one group of compounds, the other element and the increased binding energy hydrogen species are neutral. In another group of compounds, the other element and increased binding energy hydrogen species are charged such that the other element provides the balancing charge to form a neutral compound. The former group of compounds is characterized by molecular and coordinate bonding; the latter group is characterized by ionic bonding.

Also provided are novel compounds and molecular ions comprising

(a) at least one neutral, positive, or negative hydrogen species (hereinafter "increased binding energy hydrogen species") having a total energy

(i) greater than the total energy of the corresponding ordinary hydrogen species, or

(ii) greater than the total energy of any hydrogen species for which the corresponding ordinary hydrogen species is unstable or is not observed because the ordinary hydrogen species' total energy is less than thermal energies at ambient conditions, or is negative; and

(b) at least one other element.

The total energy of the hydrogen species is the sum of the energies to remove all of the electrons from the hydrogen species. The hydrogen species according to the present invention has a total energy greater than the total energy of the corresponding ordinary hydrogen species. The hydrogen species having an increased total energy according to the present invention is also referred to as an "increased binding energy hydrogen species" even though some

embodiments of the hydrogen species having an increased total energy may have a first electron binding energy less that the first electron binding energy of the corresponding ordinary hydrogen species. For example, the hydride ion of Eq. (58) for $p = 24$ has a first binding energy that is less than the first binding energy of ordinary hydride ion, while the total energy of the hydride ion of Eq. (58) for $p = 24$ is much greater than the total energy of the corresponding ordinary hydride ion.

Also provided are novel compounds and molecular ions comprising

(a) a plurality of neutral, positive, or negative hydrogen species (hereinafter "increased binding energy hydrogen species") having a binding energy

(i) greater than the binding energy of the corresponding ordinary hydrogen species, or

(ii) greater than the binding energy of any hydrogen species for which the corresponding ordinary hydrogen species is unstable or is not observed because the ordinary hydrogen species' binding energy is less than thermal energies at ambient conditions or is negative; and

(b) optionally one other element. The compounds of the invention are hereinafter referred to as "increased binding energy hydrogen compounds".

The increased binding energy hydrogen species can be formed by reacting one or more hydrino atoms with one or more of an electron, hydrino atom, a compound containing at least one of said increased binding energy hydrogen species, and at least one other atom, molecule, or ion other than an increased binding energy hydrogen species.

Also provided are novel compounds and molecular ions comprising

(a) a plurality of neutral, positive, or negative hydrogen species (hereinafter "increased binding energy hydrogen species") having a total energy

(i) greater than the total energy of ordinary molecular hydrogen, or

(ii) greater than the total energy of any hydrogen species for which the corresponding ordinary hydrogen species is unstable or is not observed because the ordinary hydrogen species' total energy is less than thermal energies at ambient conditions or is negative; and

(b) optionally one other element. The compounds of the invention are hereinafter referred to as "increased binding energy hydrogen compounds".

The total energy of the increased total energy hydrogen species is the sum of the energies to remove all of the electrons from the increased total energy hydrogen species. The total energy

of the ordinary hydrogen species is the sum of the energies to remove all of the electrons from the ordinary hydrogen species. The increased total energy hydrogen species is referred to as an increased binding energy hydrogen species, even though some of the increased binding energy hydrogen species may have a first electron binding energy less than the first electron binding energy of ordinary molecular hydrogen. However, the total energy of the increased binding energy hydrogen species is much greater than the total energy of ordinary molecular hydrogen.

In one embodiment of the invention, the increased binding energy hydrogen species can be H_n, and H_n^- where n is a positive integer, or H_n^+ where n is a positive integer greater than one. Preferably, the increased binding energy hydrogen species is H_n and H_n^- where n is an integer from one to about $1 X 10^6$, more preferably one to about $1 X 10^4$, even more preferably one to about $1 X 10^2$, and most preferably one to about 10, and H_n^+ where n is an integer from two to about $1 X 10^6$, more preferably two to about $1 X 10^4$, even more preferably two to about $1 X 10^2$, and most preferably two to about 10. A specific example of H_n^- is H_{16}^-.

In an embodiment of the invention, the increased binding energy hydrogen species can be H_n^{m-} where n and m are positive integers and H_n^{m+} where n and m are positive integers with $m < n$. Preferably, the increased binding energy hydrogen species is H_n^{m-} where n is an integer from one to about $1 X 10^6$, more preferably one to about $1 X 10^4$, even more preferably one to about $1 X 10^2$, and most preferably one to about 10 and m is an integer from one to 100, one to ten, and H_n^{m+} where n is an integer from two to about $1 X 10^6$, more preferably two to about $1 X 10^4$, even more preferably two to about $1 X 10^2$, and most preferably two to about 10 and m is one to about 100, preferably one to ten.

According to a preferred embodiment of the invention, a compound is provided, comprising at least one increased binding energy hydrogen species selected from the group consisting of (a) hydride ion having a binding energy according to Eq. (58) that is greater than the binding of ordinary hydride ion (about 0.8 eV) for $p = 2$ up to 23, and less for $p = 24$ ("increased binding energy hydride ion" or "hydrino hydride ion"); (b) hydrogen atom having a binding energy greater than the binding energy of ordinary hydrogen atom (about 13.6 eV) ("increased binding energy hydrogen atom" or "hydrino"); (c) hydrogen molecule having a first binding energy greater than about 15.3 eV ("increased binding energy hydrogen molecule" or "dihydrino"); and (d) molecular hydrogen ion having a binding energy greater than about 16.3 eV ("increased binding energy molecular hydrogen ion" or "dihydrino molecular ion").

The compounds of the present invention are capable of exhibiting one or more unique

properties which distinguishes them from the corresponding compound comprising ordinary hydrogen, if such ordinary hydrogen compound exists. The unique properties include, for example, (a) a unique stoichiometry; (b) unique chemical structure; (c) one or more extraordinary chemical properties such as conductivity, melting point, boiling point, density, and refractive index; (d) unique reactivity to other elements and compounds; (e) enhanced stability at room temperature and above; and/or (f) enhanced stability in air and/or water. Methods for distinguishing the increased binding energy hydrogen-containing compounds from compounds of ordinary hydrogen include: 1.) elemental analysis, 2.) solubility, 3.) reactivity, 4.) melting point, 5.) boiling point, 6.) vapor pressure as a function of temperature, 7.) refractive index, 8.) X-ray photoelectron spectroscopy (XPS), 9.) gas chromatography, 10.) X-ray diffraction (XRD), 11.) calorimetry, 12.) infrared spectroscopy (IR), 13.) Raman spectroscopy, 14.) Mossbauer spectroscopy, 15.) extreme ultraviolet (EUV) emission and absorption spectroscopy, 16.) ultraviolet (UV) emission and absorption spectroscopy, 17.) visible emission and absorption spectroscopy, 18.) nuclear magnetic resonance spectroscopy, 19.) gas phase mass spectroscopy of a heated sample (solids probe and direct exposure probe quadrapole and magnetic sector mass spectroscopy), 20.) time-of-flight-secondary-ion-mass-spectroscopy (TOFSIMS), 21.) electrospray-ionization-time-of-flight-mass-spectroscopy (ESITOFMS), 22.) thermogravimetric analysis (TGA), 23.) differential thermal analysis (DTA), 24.) differential scanning calorimetry (DSC), 25.) liquid chromatography/mass spectroscopy (LCMS), and/or 26.) gas chromatography/mass spectroscopy (GCMS).

According to the present invention, a hydrino hydride ion (H^-) having a binding energy according to Eq. (58) that is greater than the binding of ordinary hydride ion (about 0.8 eV) for $p = 2$ up to 23, and less for $p = 24$ (H^-) is provided. For $p = 2$ to $p = 24$ of Eq. (58), the hydride ion binding energies are respectively 3, 6.6, 11.2, 16.7, 22.8, 29.3, 36.1, 42.8, 49.4, 55.5, 61.0, 65.6, 69.2, 71.6, 72.4, 71.6, 68.8, 64.0, 56.8, 47.1, 34.7, 19.3, and 0.69 eV. Compositions comprising the novel hydride ion are also provided.

Novel compounds are provided comprising one or more hydrino hydride ions and one or more other elements. Such a compound is referred to as a hydrino hydride compound.

Ordinary hydrogen species are characterized by the following binding energies (a) hydride ion, 0.754 eV ("ordinary hydride ion"); (b) hydrogen atom ("ordinary hydrogen atom"), 13.6 eV; (c) diatomic hydrogen molecule, 15.46 eV ("ordinary hydrogen molecule"); (d) hydrogen molecular ion, 16.3 eV ("ordinary hydrogen molecular ion"); and (e) H_3^+, 22.6 eV ("ordinary trihydrogen molecular ion"). Herein, with reference to forms of hydrogen, "normal"

and "ordinary" are synonymous.

According to a further preferred embodiment of the invention, a compound is provided comprising at least one increased binding energy hydrogen species such as (a) a hydrogen atom having a binding energy of about $\frac{13.6\ eV}{\left(\frac{1}{p}\right)^2}$, preferably within ±10%,, more preferably ±5%, where p is an integer, preferably an integer from 2 to 200; (b) a hydride ion (H^-) having a binding energy of about $\frac{\hbar^2\sqrt{s(s+1)}}{8\mu_e a_0^2\left[\frac{1+\sqrt{s(s+1)}}{p}\right]^2} - \frac{\pi\mu_0 e^2\hbar^2}{m_e^2}\left(\frac{1}{a_H^3} + \frac{2^2}{a_0^3\left[\frac{1+\sqrt{s(s+1)}}{p}\right]^3}\right)$, preferably within ±10%, more preferably ±5%, where p is an integer, preferably an integer from 2 to 200; (c) $H_4^+(1/p)$; (d) a trihydrino molecular ion, $H_3^+(1/p)$, having a binding energy of about $\frac{22.6}{\left(\frac{1}{p}\right)^2}\ eV$ preferably within ±10%, more preferably ±5%, where p is an integer, preferably an integer from 2 to 200; (e) a dihydrino having a binding energy of about $\frac{15.3}{\left(\frac{1}{p}\right)^2}\ eV$ preferably within ±10%, more preferably ±5%, where p is an integer, preferably and integer from 2 to 200; (f) a dihydrino molecular ion with a binding energy of about $\frac{16.3}{\left(\frac{1}{p}\right)^2}\ eV$ preferably within ±10%, more preferably ±5%, where p is an integer, preferably an integer from 2 to 200.

According to one embodiment of the invention wherein the compound comprises a negatively charged increased binding energy hydrogen species, the compound further comprises one or more cations, such as a proton, ordinary H_2^+, or ordinary H_3^+.

A method is provided for preparing compounds comprising at least one increased binding energy hydride ion. Such compounds are hereinafter referred to as "hydrino hydride compounds". The method comprises reacting atomic hydrogen with a catalyst having a net enthalpy of reaction of about $\frac{m}{2}\cdot 27\ eV$, where m is an integer greater than 1, preferably an integer less than 400, to produce an increased binding energy hydrogen atom having a binding

energy of about $\frac{13.6\ eV}{\left(\frac{1}{p}\right)^2}$ where p is an integer, preferably an integer from 2 to 200. A further product of the catalysis is energy. The increased binding energy hydrogen atom can be reacted with an electron source, to produce an increased binding energy hydride ion. The increased binding energy hydride ion can be reacted with one or more cations to produce a compound comprising at least one increased binding energy hydride ion.

2. Hydrogen Power and Plasma Cell and Reactor

The invention is also directed to a reactor for producing a increased binding energy hydrogen compounds of the invention, such as dihydrino molecules and hydrino hydride compounds. A further product of the catalysis is plasma, light, and power. Such a reactor is hereinafter referred to as a "hydrogen reactor" or "hydrogen cell". The hydrogen reactor comprises a cell for making hydrinos. The cell for making hydrinos may take the form of a gas cell, a gas discharge cell, a plasma torch cell, or microwave power cell, for example. These exemplary cells which are not meant to be exhaustive are disclosed in Mills Prior Publications. Each of these cells comprises: a source of atomic hydrogen; at least one of a solid, molten, liquid, or gaseous catalyst for making hydrinos; and a vessel for reacting hydrogen and the catalyst for making hydrinos. As used herein and as contemplated by the subject invention, the term "hydrogen", unless specified otherwise, includes not only protcum (^1H), but also deuterium (^2H) and tritium (^3H).

The reactors described herein as "hydrogen reactors" are capable of producing not only hydrinos, but also the other increased binding energy hydrogen species and compounds of the present invention. Hence, the designation "hydrogen reactors" should not be understood as being limiting with respect to the nature of the increased binding energy hydrogen species or compound produced.

According to one aspect of the present invention, novel compounds are formed from hydrino hydride ions and cations wherein the cell further comprises an electron source. Electrons from the electron source contact the hydrinos and react to form hydrino hydride ions. The reactor produces hydride ions having the binding energy of Eq. (58). The cation may be from an added reductant, or a cation present in the cell (such as a cation comprising the catalyst).

In an embodiment, a plasma forms in the hydrogen cell as a result of the energy released from the catalysis of hydrogen. Water vapor may be added to the plasma to increase

the hydrogen concentration as shown by Kikuchi et al. [J. Kikuchi, M. Suzuki, H. Yano, and S. Fujimura, Proceedings SPIE-The International Society for Optical Engineering, (1993), 1803 (Advanced Techniques for Integrated Circuit Processing II), pp. 70-76] which is herein incorporated by reference.

3. Catalysts

3.1 Atom and Ion Catalysts

In an embodiment, a catalytic system is provided by the ionization of t electrons from a participating species such as an atom, an ion, a molecule, and an ionic or molecular compound to a continuum energy level such that the sum of the ionization energies of the t electrons is approximately $m \times 27.2\ eV$ where m is an integer. One such catalytic system involves cesium. The first and second ionization energies of cesium are $3.89390\ eV$ and $23.15745\ eV$, respectively. The double ionization ($t = 2$) reaction of Cs to Cs^{2+}, then, has a net enthalpy of reaction of $27.05135\ eV$, which is equivalent to $m = 1$ in Eq. (2a).

$$27.05135\ eV + Cs(m) + H\left[\frac{a_H}{p}\right] \rightarrow Cs^{2+} + 2e^- + H\left[\frac{a_H}{(p+1)}\right] + [(p+1)^2 - p^2] \times 13.6\ eV \quad (60)$$

$$Cs^{2+} + 2e^- \rightarrow Cs(m) + 27.05135\ eV \quad (61)$$

And, the overall reaction is

$$H\left[\frac{a_H}{p}\right] \rightarrow H\left[\frac{a_H}{(p+1)}\right] + [(p+1)^2 - p^2] \times 13.6\ eV \quad (62)$$

Thermal energies may broaden the enthalpy of reaction. The relationship between kinetic energy and temperature is given by

$$E_{kinetic} = \frac{3}{2}kT \quad (63)$$

For a temperature of 1200 K, the thermal energy is 0.16 eV, and the net enthalpy of reaction provided by cesium metal is 27.21 eV which is an exact match to the desired energy.

Hydrogen catalysts capable of providing a net enthalpy of reaction of approximately $m \times 27.2\ eV$ where m is an integer to produce hydrino whereby t electrons are ionized from an atom or ion are given *infra*. A further product of the catalysis is energy and plasma. The atoms or ions given in the first column are ionized to provide the net enthalpy of reaction of $m \times 27.2\ eV$ given in the tenth column where m is given in the eleventh column. The electrons which are ionized are given with the ionization potential (also called ionization energy or binding energy). The ionization potential of the n th electron of the atom or ion is

designated by IP_n and is given by Linde [D. R. Lide, CRC Handbook of Chemistry and Physics, 78 th Edition, CRC Press, Boca Raton, Florida, (1997), p. 10-214 to 10-216] which is herein incorporated by reference. That is for example, $Cs + 3.89390\ eV \rightarrow Cs^+ + e^-$ and $Cs^+ + 23.15745\ eV \rightarrow Cs^{2+} + e^-$. The first ionization potential, $IP_1 = 3.89390\ eV$, and the second ionization potential, $IP_2 = 23.15745\ eV$, are given in the second and third columns, respectively. The net enthalpy of reaction for the double ionization of Cs is $27.05135\ eV$ as given in the tenth column, and $m = 1$ in Eq. (2a) as given in the eleventh column.

TABLE 3. Hydrogen Ion or Atom Catalysts

Catalyst	IP1	IP2	IP3	IP4	IP5	IP6	IP7	IP8	Enthalpy	m
Li	5.39172	75.6402							81.032	3
Be	9.32263	18.2112							27.534	1
Ar	15.75962	27.62967	40.74						84.12929	3
Ar	15.75962	27.62967	40.74	59.81	75.02				218.95929	8
Ar	15.75962	27.62967	40.74	59.81	75.02	91.009	124.323		434.29129	16
K	4.34066	31.63	45.806						81.777	3
Ca	6.11316	11.8717	50.9131	67.27					136.17	5
Ti	6.8282	13.5755	27.4917	43.267	99.3				190.46	7
V	6.7463	14.66	29.311	46.709	65.2817				162.71	6
Cr	6.76664	16.4857	30.96						54.212	2
Mn	7.43402	15.64	33.668	51.2					107.94	4
Fe	7.9024	16.1878	30.652						54.742	2
Fe	7.9024	16.1878	30.652	54.8					109.54	4
Co	7.881	17.083	33.5	51.3					109.76	4
Co	7.881	17.083	33.5	51.3	79.5				189.26	7
Ni	7.6398	18.1688	35.19	54.9	76.06				191.96	7
Ni	7.6398	18.1688	35.19	54.9	76.06	108			299.96	11
Cu	7.72638	20.2924							28.019	1
Zn	9.39405	17.9644							27.358	1
Zn	9.39405	17.9644	39.723	59.4	82.6	108	134	174	625.08	23
As	9.8152	18.633	28.351	50.13	62.63	127.6			297.16	11
Se	9.75238	21.19	30.8204	42.945	68.3	81.7	155.4		410.11	15
Kr	13.9996	24.3599	36.95	52.5	64.7	78.5			271.01	10
Kr	13.9996	24.3599	36.95	52.5	64.7	78.5	111		382.01	14
Rb	4.17713	27.285	40	52.6	71	84.4	99.2		378.66	14
Rb	4.17713	27.285	40	52.6	71	84.4	99.2	136	514.66	19
Sr	5.69484	11.0301	42.89	57	71.6				188.21	7
Nb	6.75885	14.32	25.04	38.3	50.55				134.97	5
Mo	7.09243	16.16	27.13	46.4	54.49	68.8276			220.10	8
Mo	7.09243	16.16	27.13	46.4	54.49	68.8276	125.664	143.6	489.36	18
Pd	8.3369	19.43							27.767	1
Sn	7.34381	14.6323	30.5026	40.735	72.28				165.49	6
Te	9.0096	18.6							27.61	1
Te	9.0096	18.6	27.96						55.57	2
Cs	3.8939	23.1575							27.051	1
Ce	5.5387	10.85	20.198	36.758	65.55				138.89	5
Ce	5.5387	10.85	20.198	36.758	65.55	77.6			216.49	8
Pr	5.464	10.55	21.624	38.98	57.53				134.15	5
Sm	5.6437	11.07	23.4	41.4					81.514	3

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Gd	6.15	12.09	20.63	44			82.87	3
Dy	5.9389	11.67	22.8	41.47			81.879	3
Pb	7.41666	15.0322	31.9373				54.386	2
Pt	8.9587	18.563					27.522	1
He+		54.4178					54.418	2
Na+		47.2864	71.6200	98.91			217.816	8
Rb+		27.285					27.285	1
Fe3+				54.8			54.8	2
Mo2+			27.13				27.13	1
Mo4+					54.49		54.49	2
In3+				54			54	2
Ar+		27.62967					27.62967	1
Sr+		11.03	42.89				53.92	2

In an embodiment, each of the catalysts Rb^+, K^+ / K^+, and Sr^+ may be formed from the corresponding metal by ionization. The source of ionization may be UV light or a plasma. At least one of a source of UV light and a plasma may be provided by the catalysis of hydrogen with a one or more hydrogen catalysts given in TABLES 1 and 3. The catalysts may also be formed from the corresponding metal by reaction with hydrogen to form the corresponding alkali hydride or by ionization at a hot filament which may also serve to dissociate molecular hydrogen to atomic hydrogen. The hot filament may be a refractory metal such as tungsten or molybdenum operated within a high temperature range such as 1000 to 2800 °C.

A catalyst of the present invention can be an increased binding energy hydrogen compound having a net enthalpy of reaction of about $\frac{m}{2} \cdot 27\ eV$, where m is an integer greater than 1, preferably an integer less than 400, to produce an increased binding energy hydrogen atom having a binding energy of about $\frac{13.6\ eV}{\left(\frac{1}{p}\right)^2}$ where p is an integer, preferably an integer from 2 to 200.

In another embodiment of the catalyst of the present invention, hydrinos are formed by reacting an ordinary hydrogen atom with a catalyst having a net enthalpy of reaction of about

$$\frac{m}{2} \cdot 27.2\ eV \qquad (64)$$

where m is an integer. It is believed that the rate of catalysis is increased as the net enthalpy of reaction is more closely matched to $\frac{m}{2} \cdot 27.2\ eV$. It has been found that catalysts having a net enthalpy of reaction within ±10%, preferably ±5%, of $\frac{m}{2} \cdot 27.2\ eV$ are suitable for most

applications.

In an embodiment, catalysts are identified by the formation of a rt-plasma at low voltage as described in Mills publication R. Mills, J. Dong, Y. Lu, "Observation of Extreme Ultraviolet Hydrogen Emission from Incandescently Heated Hydrogen Gas with Certain Catalysts", Int. J. Hydrogen Energy, Vol. 25, (2000), pp. 919-943 which is incorporated by reference. In another embodiment, a means of identifying catalysts and monitoring the catalytic rate comprises a high resolution visible spectrometer with resolution preferable in the range 1 to 0.01 Å. The identity of a catalysts and the rate of catalysis may be determined by the degree of Doppler broadening of the hydrogen Balmer lines.

3.2 Hydrino Catalysts

In a process called *disproportionation*, lower-energy hydrogen atoms, *hydrinos*, can act as catalysts because each of the metastable excitation, resonance excitation, and ionization energy of a hydrino atom is $m \times 27.2\ eV$. The transition reaction mechanism of a first hydrino atom affected by a second hydrino atom involves the resonant coupling between the atoms of m degenerate multipoles each having $27.21\ eV$ of potential energy [Mills, *The Grand Unified Theory of Classical Quantum Mechanics*, September 2001 Edition, Chps. 5 and 6, BlackLight Power, Inc., Cranbury, New Jersey, Distributed by Amazon.com; R. Mills, P. Ray, "Spectral Emission of Fractional Quantum Energy Levels of Atomic Hydrogen from a Helium-Hydrogen Plasma and the Implications for Dark Matter", Int. J. Hydrogen Energy, Vol. 27, No. 3, pp. 301-322]. The energy transfer of $m \times 27.2\ eV$ from the first hydrino atom to the second hydrino atom causes the central field of the first atom to increase by m and its electron to drop m levels lower from a radius of $\frac{a_H}{p}$ to a radius of $\frac{a_H}{p+m}$. The second interacting lower-energy hydrogen is either excited to a metastable state, excited to a resonance state, or ionized by the resonant energy transfer. The resonant transfer may occur in multiple stages. For example, a nonradiative transfer by multipole coupling may occur wherein the central field of the first increases by m, then the electron of the first drops m levels lower from a radius of $\frac{a_H}{p}$ to a radius of $\frac{a_H}{p+m}$ with further resonant energy transfer. The energy transferred by multipole coupling may occur by a mechanism that is analogous to photon absorption involving an excitation to a virtual level. Or, the energy transferred by multipole coupling during the electron transition of the first hydrino atom may occur by a mechanism that is analogous to two photon absorption involving a first excitation to a virtual level and a second

excitation to a resonant or continuum level [B. J. Thompson, *Handbook of Nonlinear Optics*, Marcel Dekker, Inc., New York, (1996), pp. 497-548; Y. R. Shen, *The Principles of Nonlinear Optics*, John Wiley & Sons, New York, (1984), pp. 203-210; B. de Beauvoir, F. Nez, L. Julien, B. Cagnac, F. Biraben, D. Touahri, L. Hilico, O. Acef, A. Clairon, and J. J. Zondy, Physical Review Letters, Vol. 78, No. 3, (1997), pp. 440-443]. The transition energy greater than the energy transferred to the second hydrino atom may appear as a photon in a vacuum medium.

The transition of $H\left[\frac{a_H}{p}\right]$ to $H\left[\frac{a_H}{p+m}\right]$ induced by a multipole resonance transfer of $m \cdot 27.21\ eV$ and a transfer of $[(p')^2-(p'-m')^2]\ X\ 13.6\ eV - m \cdot 27.2\ eV$ with a resonance state of $H\left[\frac{a_H}{p'-m'}\right]$ excited in $H\left[\frac{a_H}{p'}\right]$ is represented by

$$H\left[\frac{a_H}{p'}\right]+H\left[\frac{a_H}{p}\right]\rightarrow H\left[\frac{a_H}{p'-m'}\right]+H\left[\frac{a_H}{p+m}\right]+[((p+m)^2-p^2)-(p'^2-(p'-m')^2)]\ X\ 13.6\ eV \quad (65)$$

where p, p', m, and m' are integers.

Hydrinos may be ionized during a disproportionation reaction by the resonant energy transfer. A hydrino atom with the initial lower-energy state quantum number p and radius $\frac{a_H}{p}$ may undergo a transition to the state with lower-energy state quantum number $(p+m)$ and radius $\frac{a_H}{(p+m)}$ by reaction with a hydrino atom with the initial lower-energy state quantum number m', initial radius $\frac{a_H}{m'}$, and final radius a_H that provides a net enthalpy of $m\ X\ 27.2\ eV$. Thus, reaction of hydrogen-type atom, $H\left[\frac{a_H}{p}\right]$, with the hydrogen-type atom, $H\left[\frac{a_H}{m'}\right]$, that is ionized by the resonant energy transfer to cause a transition reaction is represented by

$$m\ X\ 27.21\ eV+H\left[\frac{a_H}{m'}\right]+H\left[\frac{a_H}{p}\right]\rightarrow H^*+e^-+H\left[\frac{a_H}{(p+m)}\right]+[(p+m)^2-p^2-(m'^2-2m)]X13.6\ eV \quad (66)$$

$$H^*+e^-\rightarrow H\left[\frac{a_H}{1}\right]+13.6\ eV \quad (67)$$

And, the overall reaction is

$$H\left[\frac{a_H}{m'}\right]+H\left[\frac{a_H}{p}\right]\rightarrow H\left[\frac{a_H}{1}\right]+H\left[\frac{a_H}{(p+m)}\right]+\left[2pm+m^2-m'^2\right]X13.6\ eV+13.6\ eV \quad (68)$$

4. Adjustment of Catalysis Rate

It is believed that the rate of catalysis is increased as the net enthalpy of reaction is more closely matched to $m \cdot 27.2\ eV$ where m is an integer. An embodiment of the hydrogen reactor for producing increased binding energy hydrogen compounds of the invention further comprises an electric or magnetic field source. The electric or magnetic field source may be adjustable to control the rate of catalysis. Adjustment of the electric or magnetic field provided by the electric or magnetic field source may alter the continuum energy level of a catalyst whereby one or more electrons are ionized to a continuum energy level to provide a net enthalpy of reaction of approximately $m\ X\ 27.2\ eV$. The alteration of the continuum energy may cause the net enthalpy of reaction of the catalyst to more closely match $m \cdot 27.2\ eV$. Preferably, the electric field is within the range of $0.01-10^6\ V/m$, more preferably $0.1-10^4\ V/m$, and most preferably $1-10^3\ V/m$. Preferably, the magnetic flux is within the range of $0.01-50\ T$. A magnetic field may have a strong gradient. Preferably, the magnetic flux gradient is within the range of $10^{-4}-10^2\ Tcm^{-1}$ and more preferably $10^{-3}-1\ Tcm^{-1}$.

In an embodiment, the electric field E and magnetic field B are orthogonal to cause an EXB electron drift. The EXB drift may be in a direction such that energetic electrons produced by hydrogen catalysis dissipate a minimum amount of power due to current flow in the direction of the applied electric field which may be adjustable to control the rate of hydrogen catalysis.

In an embodiment of the energy cell, a magnetic field confines the electrons to a region of the cell such that interactions with the wall are reduced, and the electron energy is increased. The field may be a solenoidal field or a magnetic mirror field. The field may be adjustable to control the rate of hydrogen catalysis.

In an embodiment, the electric field such as a radio frequency field produces minimal current. In another embodiment, a gas which may be inert such as a noble gas is added to the reaction mixture to decrease the conductivity of the plasma produced by the energy released from the catalysis of hydrogen. The conductivity is adjusted by controlling the pressure of the gas to achieve an optimal voltage that controls the rate of catalysis of hydrogen. In another

embodiment, a gas such as an inert gas may be added to the reaction mixture which increases the percentage of atomic hydrogen versus molecular hydrogen.

For example, the cell may comprise a hot filament that dissociates molecular hydrogen to atomic hydrogen and may further heat a hydrogen dissociator such as transition elements and inner transition elements, iron, platinum, palladium, zirconium, vanadium, nickel, titanium, Sc, Cr, Mn, Co, Cu, Zn, Y, Nb, Mo, Tc, Ru, Rh, Ag, Cd, La, Hf, Ta, W, Re, Os, Ir, Au, Hg, Ce, Pr, Nd, Pm, Sm, Eu, Gd, Tb, Dy, Ho, Er, Tm, Vb, Lu, Th, Pa, U, activated charcoal (carbon), and intercalated Cs carbon (graphite). The filament may further supply an electric field in the cell of the reactor. The electric field may alter the continuum energy level of a catalyst whereby one or more electrons are ionized to a continuum energy level to provide a net enthalpy of reaction of approximately $m \times 27.2\ eV$. In another embodiment, an electric field is provided by electrodes charged by a variable voltage source. The rate of catalysis may be controlled by controlling the applied voltage which determines the applied field which controls the catalysis rate by altering the continuum energy level.

In another embodiment of the hydrogen reactor, the electric or magnetic field source ionizes an atom or ion to provide a catalyst having a net enthalpy of reaction of approximately $m \times 27.2\ eV$. For examples, potassium metal is ionized to K^+, rubidium metal is ionized to Rb^+, or strontium metal is ionized to Sr^+ to provide the catalyst. The electric field source may be a hot filament whereby the hot filament may also dissociate molecular hydrogen to atomic hydrogen.

5. Noble Gas Catalysts and Products

In an embodiment of the hydrogen power and plasma cell, reactor, and power converter comprising an energy cell for the catalysis of atomic hydrogen to form novel hydrogen species and compositions of matter comprising new forms of hydrogen of the present invention, the catalyst comprises a mixture of a first catalyst and a source of a second catalyst. In an embodiment, the first catalyst produces the second catalyst from the source of the second catalyst. In an embodiment, the energy released by the catalysis of hydrogen by the first catalyst produces a plasma in the energy cell. The energy ionizes the source of the second catalyst to produce the second catalyst. The second catalyst may be one or more ions produced in the absence of a strong electric field as typically required in the case of a glow discharge. The weak electric field may increase the rate of catalysis of the second catalyst such that the enthalpy of reaction of the catalyst matches $m \times 27.2\ eV$ to cause hydrogen catalysis. In

embodiments of the energy cell, the first catalyst is selected from the group of catalyst given in TABLES 1 and 3 such as potassium and strontium, the source of the second catalyst is selected from the group of helium and argon and the second catalyst is selected from the group of He^+ and Ar^+ wherein the catalyst ion is generated from the corresponding atom by a plasma created by catalysis of hydrogen by the first catalyst. For examples, 1.) the energy cell contains strontium and argon wherein hydrogen catalysis by strontium produces a plasma containing Ar^+ which serves as a second catalyst (Eqs. (15-17)) and 2.) the energy cell contains potassium and helium wherein hydrogen catalysis by potassium produces a plasma containing He^+ which serves as a second catalyst (Eqs. (12-14)). In an embodiment, the pressure of the source of the second catalyst is in the range of about 1 millitorr to about one atmosphere. The hydrogen pressure is in the range of about 1 millitorr to about one atmosphere. In a preferred embodiment, the total pressure is in the range of about 0.5 torr to about 2 torr. In an embodiment, the ratio of the pressure of the source of the second catalyst to the hydrogen pressure is greater than one. In a preferred embodiment, hydrogen is about 0.1% to about 99%, and the source of the second catalyst comprises the balance of the gas present in the cell. More preferably, the hydrogen is in the range of about 1% to about 5% and the source of the second catalyst is in the range of about 95% to about 99%. Most preferably, the hydrogen is about 5% and the source of the second catalyst is about 95%. These pressure ranges are representative examples and a skilled person will be able to practice this invention using a desired pressure to provide a desired result.

In an embodiment of the power cell and power converter the catalyst comprises at least one selected from the group of He^+, Ne^+, and Ar^+ wherein the ionized catalyst ion is generated from the corresponding atom by a plasma created by methods such as a glow discharge or inductively couple microwave discharge. Preferably, the corresponding reactor such as a discharge cell or hydrogen plasma torch reactor has a region of low electric field strength such that the enthalpy of reaction of the catalyst matches $m \times 27.2\ eV$ to cause hydrogen catalysis. In one embodiment, the reactor is a discharge cell having a hollow anode as described by Kuraica and Konjevic [Kuraica, M., Konjevic, N., Physical Review A, Volume 46, No. 7, October (1992), pp. 4429-4432]. In another embodiment, the reactor is a discharge cell having a hollow cathode such as a central wire or rod anode and a concentric hollow cathode such as a stainless or nickel mesh. In a preferred embodiment, the cell is a microwave cell wherein the catalyst is formed by a microwave plasma.

In an embodiment of the plasma cell wherein the catalyst is a cation such as at least one

selected from the group of He^+ and Ar^+ an increased binding energy hydrogen compound, iron hydrino hydride, is formed as hydrino atoms react with iron present in the cell. The source of iron may be from a stainless steel cell. In another embodiment, an additional catalyst such as strontium, cesium, or potassium is present.

6. Plasma and Light Source from Hydrogen Catalysis

Typically the emission of vacuum ultraviolet light from hydrogen gas is achieved using discharges at high voltage, synchrotron devices, high power inductively coupled plasma generators, or a plasma is created and heated to extreme temperatures by RF coupling (e.g. $> 10^6\ K$) with confinement provided by a toroidal magnetic field. Observation of intense extreme ultraviolet (EUV) emission at low temperatures (e.g. $\approx 10^3\ K$) from atomic hydrogen generated at a tungsten filament that heated a titanium dissociator and certain gaseous atom or ion catalysts of the present invention vaporized by filament heating has been reported previously [R. Mills, J. Dong, Y. Lu, "Observation of Extreme Ultraviolet Hydrogen Emission from Incandescently Heated Hydrogen Gas with Certain Catalysts", Int. J. Hydrogen Energy, Vol. 25, (2000), pp. 919-943]. Potassium, cesium, and strontium atoms and Rb^+ ionize at integer multiples of the potential energy of atomic hydrogen formed the low temperature, extremely low voltage plasma called a resonance transfer or rt-plasma having strong EUV emission. Similarly, the ionization energy of Ar^+ is 27.63 eV, and the emission intensity of the plasma generated by atomic strontium increased significantly with the introduction of argon gas only when Ar^+ emission was observed [R. Mills, "Spectroscopic Identification of a Novel Catalytic Reaction of Atomic Hydrogen and the Hydride Ion Product", Int. J. Hydrogen Energy, Vol. 26, No. 10, (2001), pp. 1041-1058]. In contrast, the chemically similar atoms, sodium, magnesium and barium, do not ionize at integer multiples of the potential energy of atomic hydrogen did not form a plasma and caused no emission.

For further characterization, the width of the 656.3 nm Balmer α line emitted from microwave and glow discharge plasmas of hydrogen alone, strontium or magnesium with hydrogen, or helium, neon, argon, or xenon with 10% hydrogen was recorded with a high resolution visible spectrometer [R. L. Mills, P. Ray, B. Dhandapani, J. He, "Comparison of Excessive Balmer α Line Broadening of Glow Discharge and Microwave Hydrogen Plasmas with Certain Catalysts", J. of Applied Physics, January, 1, (2003)]. It was found that the strontium-hydrogen microwave plasma showed a broadening similar to that observed in the glow discharge cell of 27 - 33 eV; whereas, in both sources, no broadening was observed for

magnesium-hydrogen. With noble-gas hydrogen mixtures, the trend of broadening with the particular noble gas was the same for both sources, but the magnitude of broadening was dramatically different. The microwave helium-hydrogen and argon-hydrogen plasmas showed extraordinary broadening corresponding to an average hydrogen atom temperature of 110 - 130 eV and 180 - 210 eV, respectively. The corresponding results from the glow discharge plasmas were 30 - 35 eV and 33 - 38 eV, respectively. Whereas, plasmas of pure hydrogen, neon-hydrogen, krypton-hydrogen, and xenon-hydrogen maintained in either source showed no excessive broadening corresponding to an average hydrogen atom temperature of $\approx 3\ eV$. In the case of the helium-hydrogen mixture and argon-hydrogen mixture microwave plasmas, the electron temperature T_e was measured from the ratio of the intensity of the He 501.6 nm line to that of the He 492.2 line and the ratio of the intensity of the Ar 104.8 nm line to that of the Ar 420.06 nm line, respectively. Similarly, the average electron temperature for helium-hydrogen and argon-hydrogen plasmas were high, 28,000 K and 11,600 K, respectively; whereas, the corresponding temperatures of helium and argon alone were only 6800 K and 4800 K, respectively. Stark broadening or acceleration of charged species due to high fields (e. g. over 10 kV/cm) can not be invoked to explain the microwave results since no high field was observationally present. Rather, the results may be explained by a resonant energy transfer between atomic hydrogen and atomic strontium, Ar^+, or He^{2+} which ionize at an integer multiple of the potential energy of atomic hydrogen.

A preferred embodiment of the power cell produces a plasma and may also comprise a light source of at least one of extreme ultraviolet, ultraviolet, visible, infrared, microwave, or radio wave radiation.

A light source of the present invention comprises a cell of the present invention that comprises a light propagation structure or window for a desired radiation of a desired wavelength or desired wavelength range. For example, a quartz window may be used to transmit ultraviolet, visible, infrared, microwave, and/or radio wave light from the cell since it is transparent to the corresponding wavelength range. Similarly, a glass window may be used to transmit visible, infrared, microwave, and/or radio wave light from the cell, and a ceramic window may be used to transmit infrared, microwave, and/or radio wave light from the cell. The cell wall may comprise the light propagation structure or window. The cell wall or window may be coated with a phosphor that converts one or more short wavelengths to desired longer wavelengths. For example, ultraviolet or extreme ultraviolet may be converted to visible light. The light source may provide short wavelength light directly, and the short

wavelength line emission may be used for applications known in the art such as photolithography.

A light source of the present invention such as a visible light source may comprise a transparent cell wall that may be insulated such that an elevated temperature may be maintained in the cell. In an embodiment, the wall may be a double wall with a separating vacuum space. The dissociator may be a filament such as a tungsten filament. The filament may also heat the catalyst to form a gaseous catalyst. A first catalyst may be at least one selected from the group of potassium, rubidium, cesium, and strontium metal. A second catalyst may be generated by a first. In an embodiment, at least one of helium, neon, and argon is ionized to He^+, Ne^+, and Ar^+, respectively, by the plasma formed by the catalysis of hydrogen by a first catalysts such as strontium. He^+, Ne^+, and/or Ar^+ serve as second hydrogen catalysts. The hydrogen may be supplied by a hydride that decomposes over time to maintain a desired pressure which may be determined by the temperature of the cell. The cell temperature may be controlled with a heater and a heater controller. In an embodiment, the temperature may be determined by the power supplied to the filament by a power controller.

A further embodiment of the present invention of a light source comprises a tunable light source that may provide coherent or laser light. Extreme ultraviolet (EUV) spectroscopy was recorded on microwave discharges of argon or helium with 10% hydrogen. Novel extreme ultraviolet (EUV) vibrational-series emission lines with energies that empirically matched $E_{D+vib} = 4^2 E_{D H_2^+} \pm \upsilon^* 2^2 E_{vib H_2^+(\upsilon=0\rightarrow\upsilon=1)}$, $\upsilon^* = 0,1,2,3...$ were observed from the helium-hydrogen plasma at the longer wavelengths for $\upsilon^* = 0$ to $\upsilon^* = 20$ and at the shorter wavelengths for $\upsilon^* = 0$ to $\upsilon^* = 3$ where $E_{D H_2^+}$ and $E_{vib H_2^+(\upsilon=0\rightarrow\upsilon=1)}$ are the experimental bond and vibrational energies of H_2^+, respectively [R. Mills, P. Ray, "Vibrational Spectral Emission of Fractional-Principal-Quantum-Energy-Level Hydrogen Molecular Ion", Int. J. Hydrogen Energy, Vol. 27, No. 5, (2002), pp. 533-564; R. Mills, J. He, A. Echezuria, B Dhandapani, P. Ray, "Comparison of Catalysts and Plasma Sources of Vibrational Spectral Emission of Fractional-Rydberg-State Hydrogen Molecular Ion", Vibrational Spectroscopy, submitted]. These lines having energies of υ 1.18 eV υ = integer may be a source of tunable laser light. The tunable light source of the present invention comprises at least one of the gas, gas discharge, plasma torch, or microwave plasma cell wherein the cell may comprise a laser cavity. A source of tunable laser light may be provided by the light emitted from a dihydrino molecular ion using systems and means which are known in the art as described in *Laser Handbook*, Edited by M. L. Stitch, North-Holland Publishing Company, (1979).

The light source of the present invention may comprise at least one of the gas, gas discharge, plasma torch, or microwave plasma cell wherein ions or excimers are effectively formed that serve as catalysts from a source of catalyst such as He^+, He_2^*, Ne_2^*, Ne^+, Ne^+/H^+ or Ar^+ catalysts from helium, helium, neon, neon-hydrogen mixture, and argon gases, respectively. The light may be largely monochromatic light such as line emission of the Lyman series such as Lyman α or Lyman β.

A mixture of helium and neon is the basis of a He-Ne laser. Both of these atoms are also a source of catalyst. In an embodiment of the plasma power cell such as the microwave cell, the source of catalyst comprises a mixture of helium and neon with hydrogen. Population of helium-neon lasing state (20.66 eV metastable state to an excited 18.70 eV state with the laser emission at 632. 8 nm) is pumped by the catalysis of atomic hydrogen. Examples of microwave and discharge cell which use at least one of neon or helium as a source of catalyst are given in Mills Publications [R. L. Mills, P. Ray, J. Dong, M. Nansteel, B. Dhandapani, J. He, "Vibrational Spectral Emission of Fractional-Principal-Quantum-Energy-Level Atomic and Molecular Hydrogen", Vibrational Spectroscopy, submitted, R. Mills, P. Ray, "Spectral Emission of Fractional Quantum Energy Levels of Atomic Hydrogen from a Helium-Hydrogen Plasma and the Implications for Dark Matter", Int. J. Hydrogen Energy, Vol. 27, No. 3, pp. 301-322] which are incorporated herein by reference in their entirety.

Rb^+ to Rb^{2+} and $2K^+$ to $K+K^{2+}$ each provide a reaction with a net enthalpy equal to the potential energy of atomic hydrogen. The presence of these gaseous ions with thermally dissociated hydrogen formed a plasma having strong VUV emission with a stationary inverted Lyman population. We propose an energetic catalytic reaction involving a resonance energy transfer between hydrogen atoms and Rb^+ or $2K^+$ to form a very stable novel hydride ion. Its predicted binding energy of 3.0468 eV with the fine structure was observed at 4071 Å, and its predicted bound-free hyperfine structure lines $E_{HF} = j^2 3.00213\,X10^{-5} + 3.0563\,eV$ (j is an integer) matched those observed for $j=1$ to $j=37$ to within a 1 part per 10^5. This catalytic reaction may pump a cw HI laser. The enabling description is given in Mills publications [R. Mills, P. Ray, R. Mayo, "CW HI Laser Based on a Stationary Inverted Lyman Population Formed from Incandescently Heated Hydrogen Gas with Certain Group I Catalysts", IEEE Transactions on Plasma Science, in press] which are herein incorporated by reference in their entirety.

As given in R.L.Mills, P. Ray, R. M. Mayo, "CW HI Laser Based on a Stationary Inverted Lyman Population Formed from Incandescently Heated Hydrogen Gas with Certain

Group I Catalysts", IEEE Transactions on Plasma Science, in press: Then the inverted population is explained by a resonant energy transfer between hydrogen and potassium or rubidium catalysts to yield fast $H(n=1)$ atoms. The emission of excited state H from fast $H(n=1)$ atoms excited by collisions with the background H_2 has been discussed by Radovanov et al. [S. B. Radovanov, K. Dzierzega, J. R. Roberts, J. K. Olthoff, "Time-resolved Balmer-alpha emission from fast hydrogen atoms in low pressure, radio-frequency discharges in hydrogen", Appl. Phys. Lett., Vol. 66, No. 20, (1995), pp. 2637-2639]. Collisions with oxygen may also play a role in the inversion since inverted hydrogen populations are observed in the case of alkali nitrates and water vapor plasmas [R. Mills, P. Ray, R. M. Mayo, "Stationary Inverted Balmer and Lyman Populations for a CW HI Water-Plasma Laser", IEEE Transactions on Plasma Science, submitted]. Formation of H^* is also predicted which is far from thermal equilibrium in terms of the hydrogen atom temperature. Akatsuka et al. [H. Akatsuka, M. Suzuki, "Stationary population inversion of hydrogen in arc-heated magnetically trapped expanding hydrogen-helium plasma jet", Phys. Rev. E, Vol. 49, (1994), pp. 1534-1544] show that it is characteristic of cold recombining plasmas to have the high lying levels in local thermodynamic equilibrium (LTE); whereas, population inversion is obtained when T_e suddenly decreases concomitant with rapid decay of the lower lying states.

As a consequence of the nonradiative energy transfer of $m \cdot 27.2\ eV$ to the catalyst, the hydrogen atom becomes unstable and emits further energy until it achieves a lower-energy nonradiative state having a principal energy level given by Eq. (1). Thus, these intermediate states also correspond to an inverted population, and the emission from these states with energies of $q \cdot 13.6\ eV$ where $q = 1,2,3,4,6,7,8,9,11,12$ shown in Refs. 14 and 19 may be the basis of a laser in the EUV and soft X-ray, since the excitation of the corresponding relaxed Rydberg state atoms $H(1/(p+m))$ requires the participation of a nonradiative process [H. Conrads, R. Mills, Th. Wrubel, "Emission in the Deep Vacuum Ultraviolet from a Plasma Formed by Incandescently Heating Hydrogen Gas with Trace Amounts of Potassium Carbonate", Plasma Sources Science and Technology, submitted].

7. Energy Reactor

An energy reactor 50, in accordance with the invention, is shown in FIGURE 1 and comprises a vessel 52 which contains an energy reaction mixture 54, a heat exchanger 60, and a power converter such as a steam generator 62 and turbine 70. The heat exchanger 60 absorbs heat released by the catalysis reaction, when the reaction mixture, comprised of hydrogen and a

catalyst reacts to form lower-energy hydrogen. The heat exchanger exchanges heat with the steam generator 62 which absorbs heat from the exchanger 60 and produces steam. The energy reactor 50 further comprises a turbine 70 which receives steam from the steam generator 62 and supplies mechanical power to a power generator 80 which converts the steam energy into electrical energy, which can be received by a load 90 to produce work or for dissipation.

The energy reaction mixture 54 comprises an energy releasing material 56 including a source of hydrogen isotope atoms or a source of molecular hydrogen isotope, and a source of catalyst 58 which resonantly remove approximately $mX27.21\ eV$ to form lower-energy atomic hydrogen and approximately $mX48.6\ eV$ to form lower-energy molecular hydrogen where m is an integer wherein the reaction to lower energy states of hydrogen occurs by contact of the hydrogen with the catalyst. For example, He^+ fulfills the catalyst criterion—a chemical or physical process with an enthalpy change equal to an integer multiple of 27.2 eV since it ionizes at 54.417 eV which is $2 \cdot 27.2\ eV$. The catalysis releases energy in a form such as heat and lower-energy hydrogen isotope atoms and/or molecules.

The source of hydrogen can be hydrogen gas, dissociation of water including thermal dissociation, electrolysis of water, hydrogen from hydrides, or hydrogen from metal-hydrogen solutions. In all embodiments, the source of catalysts can be one or more of an electrochemical, chemical, photochemical, thermal, free radical, sonic, or nuclear reaction(s) or inelastic photon or particle scattering reaction(s). In the latter two cases, the present invention of an energy reactor comprises a particle source 75b and/or photon source 75a to supply the catalyst. In these cases, the net enthalpy of reaction supplied corresponds to a resonant collision by the photon or particle. In a preferred embodiment of the energy reactor shown in FIGURE 1, atomic hydrogen is formed from molecular hydrogen by a photon source 75a such as a microwave source or a UV source.

The photon source may also produce photons of at least one energy of approximately $mX27.21\ eV$, $\frac{m}{2}X27.21\ eV$, or $40.8\ eV$ causes the hydrogen atoms undergo a transition to a lower energy state. In another preferred embodiment, a photon source 75a producing photons of at least one energy of approximately $mX48.6\ eV$, $95.7\ eV$, or $mX31.94\ eV$ causes the hydrogen molecules to undergo a transition to a lower energy state. In all reaction mixtures, a selected external energy device 75, such as an electrode may be used to supply an electrostatic potential or a current (magnetic field) to decrease the activation energy of the reaction. In another embodiment, the mixture 54, further comprises a surface or material to dissociate and/or absorb atoms and/or molecules of the energy releasing material 56. Such surfaces or

materials to dissociate and/or absorb hydrogen, deuterium, or tritium comprise an element, compound, alloy, or mixture of transition elements and inner transition elements, iron, platinum, palladium, zirconium, vanadium, nickel, titanium, Sc, Cr, Mn, Co, Cu, Zn, Y, Nb, Mo, Tc, Ru, Rh, Ag, Cd, La, Hf, Ta, W, Re, Os, Ir, Au, Hg, Ce, Pr, Nd, Pm, Sm, Eu, Gd, Tb, Dy, Ho, Er, Tm, Vb, Lu, Th, Pa, U, activated charcoal (carbon), and intercalated Cs carbon (graphite).

In an embodiment, a catalyst is provided by the ionization of t electrons from an atom or ion to a continuum energy level such that the sum of the ionization energies of the t electrons is approximately $m \times 27.2\ eV$ where t and m are each an integer. A catalyst may also be provided by the transfer of t electrons between participating ions. The transfer of t electrons from one ion to another ion provides a net enthalpy of reaction whereby the sum of the ionization energy of the electron donating ion minus the ionization energy of the electron accepting ion equals approximately $m \cdot 27.2\ eV$ where t and m are each an integer.

In a preferred embodiment, a source of hydrogen atom catalyst comprises a catalytic material 58, that typically provide a net enthalpy of approximately $m \times 27.21\ eV$ plus or minus $1\ eV$. In a preferred embodiment, a source of hydrogen molecule catalysts comprises a catalytic material 58, that typically provide a net enthalpy of reaction of approximately $m \times 48.6\ eV$ plus or minus $5\ eV$. The catalysts include those given in TABLES 1 and 3 and the atoms, ions, molecules, and hydrinos described in Mills Prior Publications which are incorporated herein by reference.

A further embodiment is the vessel 52 containing a catalysts in the molten, liquid, gaseous, or solid state and a source of hydrogen including hydrides and gaseous hydrogen. In the case of a reactor for catalysis of hydrogen atoms, the embodiment further comprises a means to dissociate the molecular hydrogen into atomic hydrogen including an element, compound, alloy, or mixture of transition elements, inner transition elements, iron, platinum, palladium, zirconium, vanadium, nickel, titanium, Sc, Cr, Mn, Co, Cu, Zn, Y, Nb, Mo, Tc, Ru, Rh, Ag, Cd, La, Hf, Ta, W, Re, Os, Ir, Au, Hg, Ce, Pr, Nd, Pm, Sm, Eu, Gd, Tb, Dy, Ho, Er, Tm, Vb, Lu, Th, Pa, U, activated charcoal (carbon), and intercalated Cs carbon (graphite) or electromagnetic radiation including UV light provided by photon source 75. Alternatively, the hydrogen is dissociated in a plasma.

The present invention of an electrolytic cell energy reactor, plasma electrolysis reactor, barrier electrode reactor, RF plasma reactor, pressurized gas energy reactor, gas discharge energy reactor, microwave cell energy reactor, and a combination of a glow discharge cell and

a microwave and or RF plasma reactor of the present invention comprises: a source of hydrogen; one of a solid, molten, liquid, and gaseous source of catalyst; a vessel containing hydrogen and the catalyst wherein the reaction to form lower-energy hydrogen occurs by contact of the hydrogen with the catalyst; and a means for removing the lower-energy hydrogen product. The present energy invention is further described in Mills Prior Publications which are incorporated herein by reference.

In a preferred embodiment, the catalysis of hydrogen produces a plasma. The plasma may also be at least partially maintained by a microwave generator wherein the microwaves are tuned by a tunable microwave cavity, carried by a waveguide, and are delivered to the reaction chamber though an RF transparent window or antenna. The microwave frequency may be selected to efficiently form atomic hydrogen from molecular hydrogen. It may also effectively form ions or excimers that serve as catalysts from a source of catalyst such as He^+, He_2^*, Ne_2^*, Ne^+/H^+ or Ar^+ catalysts from helium, helium, neon, neon-hydrogen mixture, and argon gases, respectively. . In an embodiment, the cell provides a catalyst for a source of catalyst such as He^+, Ar^+, and Ne^+ from helium, argon, and neon gas, respectively. In embodiments, cell types may be combined for based on specific functions. For example, a glow discharge cell which is very effective at producing catalyst for a source of catalyst such as He^+, Ar^+, and Ne^+ from helium, argon, and neon gas, respectively, may be combined with a reactor such as a microwave reactor that is well suited for the production of atomic hydrogen to react with the catalyst.

8. Hydrogen Microwave Plasma and Power Cell and Reactor

A hydrogen microwave plasma and power cell and reactor of the present invention for the catalysis of atomic hydrogen to form increased-binding-energy-hydrogen species and increased-binding-energy-hydrogen compounds comprises a vessel having a chamber capable of containing a vacuum or pressures greater than atmospheric, a source of atomic hydrogen, a source of microwave power to form a plasma, and a catalyst capable of providing a net enthalpy of reaction of $m/2 \cdot 27.2 \pm 0.5\ eV$ where m is an integer, preferably m is an integer less than 400. The source of microwave power may comprise a microwave generator, a tunable microwave cavity, waveguide, and an antenna. Alternatively, the cell may further comprise a means to at least partially convert the power for the catalysis of atomic hydrogen to microwaves to maintain the plasma.